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BULLETIN OF THE SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION

Vol. V LANCASTER, PA., JUNE, 1915 No. 10

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BULLETIN

OF THE

Society for the Promotion of Engineering Education

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EDITORIALS.

Local Sections of the Society.—The establishment at the Kansas State Agricultural College of the first local section of this Society brings distinctly before the Society the importance and value of local associations for the discussion of questions pertaining to teaching. These discussions might well be transmitted in brief form for publication in the BULLETIN, since we all appreciate the fact that the discussions are usually fully as interesting as the papers. Most teachers in engineering schools think more of the technical knowledge of the subject than of the methods and means of presenting them to their students. While no one will question for a minute the importance of the technical knowledge of the subject for the teacher, everyone on the other hand, must appreciate the fact that the method of presentation is also of great importance. It is the intention of the publication committee to publish in the BULLETIN articles which are of general interest to engineering educators, and which can be discussed to advantage by small groups of teachers. A local section of this Society, especially where a number of institutions could be represented in the same section, would form a center of engineering education of the greatest importance. It is to be hoped that this matter will be further discussed at the Ames meeting both before the council and the institutional delegates.

Teaching the Electric Circuit.—Every teacher in electrical engineering of experience will recognize an old acquaintance in the question raised by Mr. Wilson in his article "Teaching the Electric Current *vs.* Teaching Direct and Alternating Current," printed in the May BULLETIN. In presenting the direct current first the student undoubtedly builds up his knowledge of the science by the study of a special case. After a science has become so well formulated as the electrical science, it might seem that the logical order of presentation would be to develop the general laws first, but when it is remembered that this science in common with others was developed and formulated by the observation and study of special phenomena it

does not seem so illogical as at first. The real test is, of course, the results obtained for a given expenditure of time and energy. Perhaps one reason why we continue to consider continuous and alternating currents separately and in that order is because practically all of the text-books in common use have so developed the subject. While this may not be a sufficient reason for continuing in this manner indefinitely, it is significant that of all the eminent engineers who have been both teachers and writers, none has developed a complete course based on the inverse order of presentation. The occasional texts that have appeared do not as a rule fit into a curriculum already organized. Many scientific truths have to be presented to the student in the guise of experimental facts and the general laws developed later. It is the business of the instructor to see that as each separate fact and phenomenon is presented the student shall properly classify them under the fundamental laws. It is hoped that Mr. Wilson's paper may lead others to give expression to their experiences in dealing with the same question.

PERSONALS.

After forty-one years of service Professor Ira O. Baker has resigned as head of the department of civil engineering. He will not, happily for the University, sever his connection with the department but continue as professor of civil engineering teaching certain subjects to which he has given life-time attention. Dr. Baker has been identified with the engineering college practically since its inception and the civil engineering department may be said without detracting from the importance of the assistance of his colleagues, to be the product of his efforts. The activities of Dr. Baker have been widespread and effective. Aside from building up a great department of civil engineering he has written authoritative books on concrete and masonry construction, road pavements, etc., which are recognized and used the country over. The Society for the Promotion of Engineering Education is a conception of

his and its present flourishing condition is due in no small measure to his early work and continued support. He was its first president. Colleagues and students alike regret that time in its relentlessness could not have passed Dr. Baker by and permitted him to preside indefinitely over the destinies of the department which he has so successfully built up.

SOCIETY NOTES.

The readers of the BULLETIN will be interested in knowing that Major-General George W. Goethals has promised an article on the "West Point Type of Training for Engineers," to be published in the late fall or early winter.

The Secretary was present at the dedication of the new engineering building of the Johns Hopkins University. The buildings and equipment are a gift from the state of Maryland of $650,000, together with the annual appropriation of $50,000 for maintenance. The two buildings dedicated on May 21 were the engineering buildings, to be devoted to mechanical and electrical engineering, and the power plant. The engineering building also temporarily houses the department of civil engineering pending the erection of a special building this summer. The power plant which will furnish power for the University is also well equipped for a power laboratory. The buildings are exceedingly well designed for their purposes, thoroughly lighted both for day and evening work, and especially well arranged for research. A detailed description will be published in the BULLETIN early next fall.

Delegates to the 1915 Meeting.—The secretary has been notified of the appointment of the following institutional delegates to the Ames Meeting: Case School of Applied Science, Chas. S. Howe, president; University of Notre Dame, Professor Martin McCue; Princeton University, Professor F. H. Constant, Howard C. Phillips, trustee; University of North Dakota, Dean Calvin H. Crouch; Drexel Institute, Hollis Godfrey, President; George Washington University, Dean H. L. Hodgkins; Municipal University of Akron, Fred E. Ayres,

president; Worcester Polytechnic Institute, Ira N. Hollis, president; Cornell University, Professor Chas. Lee Crandall; University of Wisconsin, Dean F. E. Turneaure; State University of Iowa, Professor J. B. Hill; Kansas State Agricultural College, Dean A. A. Potter; University of California, Dean C. L. Cory; Rutgers College, Professor H. N. Lendall; University of Utah, Director Jos. F. Merrill; University of Pittsburgh, S. B. McCormick, chancellor; Iowa State College, Vice-Dean S. W. Beyer; University of Kansas, Dean P. F. Walker; University of Virginia, Professor W. S. Rodman; University of Michigan, Professor J. F. Wilson.

Classification of Technical Literature.—Delegates from about twenty national technical and scientific societies met in the United Engineering Society Building, 29 West 39th Street, New York City, on May 21, 1915, to perfect a permanent organization, the purpose being to prepare a classification of the literature of applied science which might be generally accepted and adopted by these and other organizations.

There was a generally expressed opinion that such a classification, if properly prepared, might well serve as a basis for the filing of clippings, for cards in a card index, and for printed indexes; and that the publishers of technical periodicals might be induced to print against each important article the symbol of the appropriate class in this system, so that by clipping these articles a file might be easily made which would combine in one system these clippings, together with trade catalogues, maps, drawings, blue prints, photographs, pamphlets and letters classified by the same system.

By request, Mr. W. P. Cutter, the librarian of the Engineering Societies' Library, and a delegate from the American Institute of Mining Engineers, read a paper on "The Classification of Applied Science," in which, after describing the existing classifications, of one of which he is the author, stated that, in his opinion, no one of these, although having excellent features, was complete and satisfactory enough to be worthy of general adoption. He outlined a plan whereby a central office could

collate all the existing classifications, and, with the help of specialists in the various national societies interested, might compile a general system, which although perhaps not absolutely perfect, might meet with general acceptance and adoption.

Permanent organization was effected by the election of the following officers: Chairman, Fred R. Low; Secretary, W. P. Cutter; Executive Committee, the above, with Edgar Marburg, H. W. Peck, Samuel Sheldon.

It was agreed that a special invitation to participate by the appointment of a delegate be sent to other national societies which might be interested in the general plan.

The following societies were represented by delegates: Samuel Sheldon, Library Board, United Engineering Society; Richard Moldenke, American Foundrymen's Association; C. Clifford Kuh, Society for Electrical Development; Cullen W. Parmelee, American Ceramic Society; Sullivan W. Jones, J. A. F. Cardiff, American Institute of Architects; Geo. F. Weston, American Society of Agricultural Engineers; F. L. Pryor, American Society of Refrigerating Engineers; H. W. Peck, American Gas Institute; Nicholas Hill, American Water Works Association; Edwin J. Prindle, L. P. Alford, L. P. Breckenridge, American Society of Mechanical Engineers; F. J. T. Stewart, National Fire Protection Association; J. J. Blackmore, American Society of Heating and Ventilating Engineers; C. F. Clarkson, Society of Automobile Engineers; F. L. Bishop, Society for the Promotion of Engineering Education; George R. Olshausen, U. S. Bureau of Standards; E. C. Crittenden, American Physical Society; Alfred Rigling, Franklin Institute; W. P. Cutter, American Institute of Mining Engineers; Edgar Marburg, American Society for Testing Materials; A. S. MacAllister, National Electric Light Association, American Electro Chemical Society and Illuminating Engineering Society; C. E. Lindsay, American Railway Engineering Association; G. W. Lee, Librarian.

The Executive Committee was charged with the task of

enlarging the membership of the committee to include delegates from all similar national organizations, and the preparation of a plan for further action.

The delegates present expressed most hearty and enthusiastic personal interest in any system which might be worthy of general adoption; they could, of course, not promise at this early date, anything more than moral support to the idea, reserving for themselves and for their societies the right to thoroughly examine any system that might be evolved before recommending its adoption.

The name adopted for this organization is "Joint Committee on Classification of Technical Literature," and the temporary address of the Secretary, Mr. W. P. Cutter, is 29 West 39th Street, New York City.

NEW MEMBERS.

BRAY, G. E., Industrial Engineer, Kansas State Agricultural College, Manhattan, Kans.

GEARHART, W. S., State Engineer, Professor of Highway Engineering, Kansas State Agricultural College, Manhattan, Kans.

HAYES, THORNTON, Instructor in Machine Tool Work, Foreman, Machine Shop, Kansas State Agricultural College, Manhattan, Kans.

PAINE, F. D., Assistant Professor Electrical Engineering, Iowa State College, Ames, Iowa.

PIPER, F. F., Instructor in Electrical Engineering, Mechanics Institute, Rochester, N. Y.

APPLICANTS FOR MEMBERSHIP.

ALLEE, WALTER G., Instructor in Physics, Kansas State Agricultural College, Manhattan, Kans.

BAEBENROTH, A. C., Professor of English, Head of the Dept. of English, L. C. Smith College of Applied Science, Syracuse University, Syracuse, N. Y.

FLOYD, E. V., Assistant Professor of Physics, Kansas State Agricultural College, Manhattan, Kans.

HAY, EARL D., Professor of Drawing and Machine Design, Oshkosh Normal School, Oshkosh, Wis.

HEWITT, CHAS. E., Dean of Engineering, New Hampshire College of A. & M. Arts, Durham, N. H.

LYNCH, DANIEL E., Instructor in Forging, Kansas State Agricultural College, Manhattan, Kans.

WEINBACH, M. P., Assistant Professor of Electrical Engineering, University of Missouri, Columbia, Mo.

BOOKS RECEIVED.

Tables and Formulas. By WILLIAM RAYMOND LONGLEY. Published by Ginn and Co., Boston.

BOOK REVIEWS.

Tables and Formulas. (Revised edition.) By WILLIAM RAYMOND LONGLEY, Assistant Professor of Mathematics, Sheffield Scientific School, Yale University. 12mo, cloth, v + 31 pages, 50 cents net. Ginn and Co. 1915.

A small sized book for student use. It contains such formulas and tables as are commonly required in solving numerical problems in analytic geometry, calculus, and applied mathematics. It would not take the place of the more complete work for the private library, but would furnish to the student the convenience in the use of logarithms, trigonometric functions, and standard differential and integral forms, that the slide rule furnishes in simple calculations.

L. H. H.

Steam Charts. By F. O. ELLENWOOD, Assistant Professor of Heat Power Engineering, Cornell University. John Wiley & Sons, New York. 1914. 91 Pages. $7 \times 9\frac{1}{2}$. Price $1.00.

This book contains fundamental equations, formula, and diagrams of thermodynamics and accurate steam charts covering a wide range of conditions. It furnishes a collection of reliable data in a convenient and durable book form.

The book should prove valuable for reference to the student and engineer in that he could readily refresh his memory on some of the fundamental theory without going into too much detail and at the same time have available typical examples showing the method of procedure in the use of the comprehensive charts furnished.

J. W.

American Hand Book for Electrical Engineers. HAROLD PENDER, Editor-in-Chief, Professor of Electrical Engineering, University of Pennsylvania, and Associate Editors. Morocco, $5.00 net (21/—net), 2050 pages $4\frac{1}{2} \times 7$, illustrated. John Wiley and Sons, Inc. 1914.

This, the third of its kind on the market, differs from its predecessors chiefly in the arrangement of the material, which is alphabetical instead of being arranged under large main divisions of electrical engineering. An added and valuable feature is the copious cross references at the beginning of each article and the bibliography at the close. The book is prepared primarily for practicing engineers and because of this the so-called practical and theoretical have been kept as distinct as the subject would permit. Each topic or article is written by a specialist and the author's name printed at the end of the article, which gives added confidence in the text.

L. H. H.

COLLEGE NOTES.

Michigan Agricultural College.—The Legislature, which has just adjourned, passed a bill increasing the tax levy for the Michigan Agricultural College from one tenth to one fifth mill.

The special interest attaching to this information for the readers of the BULLETIN lies in the fact that two years ago the Legislature passed an act granting a substantial increase in the levy for the College, but attached thereto a provision limiting the faculty of all college funds for engineering instruction to a ridiculously small amount, about one half of the current budget for engineering. The College contested this bill and the supreme court of Michigan declared that it was unconstitutional. The bill first referred to above, and which is now a law, has no strings to it. Therefore, the engineering interests at the College are well pleased with the situation.

University of Illinois.—With the accession of Dr. F. H. Newell former Director of the U. S. Reclamation Service to the headship of the department vacated by Dr. Baker, Illinois

feels that it is indeed fortunate. Dr. Newell is qualified by long professional training for the position he has accepted. He graduated from Massachusetts Institute of Technology in 1885 in mining engineering and took post-graduate work in geology and hydraulics. In 1888 he was appointed Assistant Hydraulic Engineer of the U. S. Geological Survey. He continued for twenty-six years in the employ of the government serving later as Chief Engineer and then as Director of the Reclamation Service.

Prof. C. R. Richards, Acting Dean of the College of Engineering, recently made a three-weeks' tour of engineering schools in the east; visiting University of Michigan, University of Toronto, McGill Unviersity, Union College, Worcester Polytechnic Institute, Massachusetts Institute of Technology, Harvard University, Pennsylvania State College, University of Pittsburgh and Carnegie Institute of Technology.

Recent visitors at the University have included Dean F. E. Turneaure, of the University of Wisconsin, Prof. E. R. Hedrick, of the University of Missouri, and W. W. Carlson, Associate Professor of Shop Practice, Kansas Agricultural College.

Mr. F. H. Newell gave three illustrated lectures on April 21, 22 and 23 dealing with various phases of the work of the reclamation service.

The State Legislature is in session and one of the questions up for discussion is the mill tax law which was passed two years ago. Revenues for the University from the state accruing under the mill tax equals $4,573,000 for the biennium 1915–16. Under provisions of the law the legislature appropriates the entire sum in one amount for the Board of Trustees to spend as they may decide. It is sought to vest power in the legislature to appropriate amounts to various uses instead of by the prevailing practice. Naturally the University prefers the former method, as it affords more elasticity in administration and greater efficiency in distribution of funds.

University of Minnesota.—The students of the Extension classes in Architecture of the College of Engineering of the

University of Minnesota, held a dinner Friday, May 7, to mark the successful completion of the year's work. After the dinner possibilities for future development of Extension Work in Architecture were discussed and a permanent organization was effected along the lines of the French architectural "ateliers." N. L. Larson was elected "Massier" and M. Knudston, "Sousmassier." In the last Beaux Arts Society competition, members of this class sent eight plan problems to New York for exhibition and judgment. All of the designs were successful in receiving the award of "Mention."

The American Society of Mechanical Engineers and the American Institute of Electrical Engineers held a joint meeting in the auditorium of the Main Engineering Building on the evening of May 10, to which members of the student branches were invited.

The Hydro Electric Plant of the Minneapolis General Electric Company at St. Croix Falls was visited and inspected on Saturday, May 15, by a party aggregating 125 students and members of the Faculty of the College of Engineering of the University of Minnesota. This trip is one of a series of inspections of engineering plants by students of the Freshman class in the course in technology.

Professor W. H. Kavanaugh, head of the Experimental Engineering Department, University of Minnesota, has been appointed a member of the International Jury of Award, Department of Machinery, at the Panama Exposition, San Francisco. Professor Kavanaugh will spend the month of May at the Exposition judging exhibits.

University of Pennsylvania.—Prof. R. H. Fernald recently delivered a lecture on "Producer Gas Problems" before the students of Sheffield Scientific School, Yale University, New Haven, Conn.

The requirement of senior thesis has been discontinued this year in the department of Electrical Engineering, and an advanced course in electrical laboratory substituted.

During the past year the following lectures have been de-

livered, at which attendance has been required of the senior and junior engineers: Mr. A. L. A. Himmelwright, consulting engineer, New York City, on "Fire Hazard to Life in High Buildings"; Mr. C. D. Pierce, executive assistant Barber Asphalt Paving Co., Philadelphia, Pa., on "Lake Asphalt and its Application in the Building of Streets and Roads"; Mr. William Kent, consulting engineer, New York City, on "Engineering Common Sense"; Mr. F. N. Speller, metallurgical engineer, National Tube Co., Pittsburgh, Pa., on "Manufacture of Lap Welded and Seamless Steel Tubular Products"; Mr. William McClellan, consulting engineer, New York City, on "Professional Engineers and Governmental Regulation"; Mr. Carl Herring, consulting engineer, Philadelphia, Pa., on "Book Knowledge *vs.* Practice"; Mr. R. W. Lesley, on "The Growth of a Great Industry: Portland Cement and Its Use."

A test under the supervision of Mr. G. S. Wheatley, instructor in experimental engineering, was recently made by the senior mechanical, electrical and chemical engineers on the pumping station of the Springfield Consolidated Water Co., at Neshaminy Falls, Pa. The test was of a week's duration and comprised a complete test of boilers, engines, pumps and auxiliaries.

Yale University.—The Sheffield Scientific School seniors in Mechanical Engineering took their annual inspection trip March 24 to 31 inclusive. There were 77 students in the party, which was under the direction of Professors L. P. Breckenridge, J. W. Roe and Mr. H. L. Seward.

The first part of the trip included inspections of industrial plants at Hartford, Conn., Springfield and Worcester, Mass., and Providence, R. I. While in Providence a joint meeting was held with the seniors in Mechanical Engineering of Brown University. From Providence the party went by way of the Fall River Line on the steamer *Plymouth* to New York. An opportunity was given for the inspection of the engines and machinery of the boat. Sunday and Monday were spent in New York City. On Sunday the party visited the East Side

section under the guidance of the Industrial Committee of the Y. M. C. A. Monday was spent visiting the Engineering Societies Building and industrial plants. March 30 and 31 were spent in and around Philadelphia. While there Mr. James M. Dodge gave an interesting talk to the students on the work of Frederick W. Taylor. On the trip about twenty-five industrial plants of varying types were visited and studied.

A PROPOSED REORGANIZATION OF ENGINEERING INSTRUCTION IN THE FRESHMAN AND SOPHOMORE YEARS.

BY LEWIS ELLSWORTH AKELEY,

Dean, School of Engineering, University of South Dakota.

From time to time there have been discussions of more or less radical propositions involving reorganization of engineering education. Notable among these was Professor Karapetoff's concentric method of engineering education, and there have been others.

One might draw up specifications for the design of courses of instruction for engineering students. Into these specifications might be placed all the demands, so far as performance is concerned, made by all the radical proposals of engineering reformers and also the requirements insisted upon by all the critics of these proposals. In such a seemingly remarkable procedure the assumption would be, that both reformers and critics have clear intuitions of what should be the practical working of an ideal system of instruction. Critic and reformer disagree only in regard to the means of securing ends universally regarded as desirable. But our specification would deal only with the ends to be secured. These ends would not then be mutually inconsistent. But many would say that, in view of the instrumentalities that must be employed to secure these ends, our specification would be making demands mutually incompatible one with another.

If you would give to an engineer of fifteen years ago specifications for a modern power plant, he would say the demands are incompatible. Engineering science has made compatible requirements seemingly not so.

Whenever there is chaos in human opinion, as there is today in educational ideas, is it not often due to the fact that

we are failing to recognize some fundamental law of nature or mind?

I am going to name such a law of mind that is today being disregarded and to suggest that, if it were seriously considered and we had the courage to apply it consistently, we would find it quite feasible to meet the demand of such specifications as those indicated above.

The business of the engineer is to solve problems, in the broadest sense in which the term problem can be used. We will call the process of problem solution, reasoning. Defining reasoning in this way a modern psychologist states four conditions that must be fulfilled in reasoning. We need notice only the first one, for that is the one that is being disregarded in our educational procedure.

"Every act of reasoning is closely related to the felt need or purpose of the individual at the moment. This is purely subjective in its origin and an expression of much in the earlier history of that individual and in his immediately preceding life. It is connected with the desire and these go back to early training; with life purpose, however originated; and finally, with instinct. The purpose cannot in its turn be understood apart from the larger whole of the life of the individual, although the momentary purpose is sufficient to enable one to understand the course of reasoning."*

In our present instruction we regard only the momentary purposes. For that is enough to make the course of reasoning understood by the logical mind of the teacher. The reasoning is not the student's own, because his life purpose is in no way challenged by the problem set before him. In other words, we give our students a problem in physics or electrical engineering. He solves one quite different from the one we give him. His own problem is, how may he successfully meet these curious and peculiar expectations of his instructor. We think he is studying physics. No, he is studying his instructor. The problem in physics plays a subordinate part in his

* Pillsbury, "Psychology of Reasoning," p. 9.

own problem. Later in the course he *finds* himself, in engineering study, and a real life purpose functions in all his reasoning. But in the freshman and sophomore years our work with him suffers seriously in efficiency because we aim at one thing in our dealings with him; we achieve quite another. We are blind to our own achievement. We vainly imagine that we are actually doing what we are trying to do. The student cannot reason in the way we expect him to. It is not in human nature to do so, because that act of reasoning is not "related to felt need or purpose of the individual," "connected with his life purpose," "with instinct," "a purpose that cannot be understood apart from the larger whole of the life of the individual."

This fundamental condition for successful reasoning calls for a radical re-arrangement of educational material. Today it is organized with its elements *logically* subordinated one to another. On the basis of the above psychological principle this material should be arranged to fulfill a hierarchy of purposes. It should be aimed, not at the student's logical machine, but at his *will*. Every individual "problem" that makes up the whole course should, when it is attacked by the student, be in the focus of his own purposes, his life purpose in the background; the immediate purpose in the foreground. The whole pressure of his life should be directed against the immediate problem which at that moment constitutes the most prominent obstacle in the way of realizing all that is in him.

Such a reorganization of the subject matter of engineering education demands not merely a knowledge of engineering science and of the laws of the human mind but the labors of one who is the master of a difficult art. Here we are dealing with life, not with a machine. The merits of such a solution of the educational problem here advocated can never be fairly tested as all scientific propositions must be tested, by their practical working, until the engineer and the psychologist and the practical teacher, all embodied in one consciousness, have given the proposition a form in which it is ready to be tested.

We cannot wait for the appearance of any such genius. It is important to formulate the problem properly and to make some tentative effort to solve it.

A proposition has been made for a very expensive testing of the practical working of various educational methods now in use. On the face of it, such a procedure can give us nothing more than a decision of the relative merits of methods now employed. The great need is a method better and more efficient than any now in use. Before the scientific testing and verification of a method can be made, the equally serious matter of creating a method must come. The creative work in the designing of new methods in harmony with the best modern thought and with the intuition of the best teachers has hardly more than begun. It is premature to begin any expensive or systematically organized system of testing the workings of current educational methods.

Educational material then is to be organized with relation to life purpose. Now, life purpose has something to do with vocational purpose. To reach the student's will on vocational lines means to present the subject studied in such a manner as to promote vocational choice on the part of the student. Educational experts may help him in the choice of a vocation, but the principle here considered demands the student's own coöperation in making that choice.

We then begin with modern industrial problems as a whole. Abstract from the concrete power plant, say, some aspect for initial study that will relate itself to life purposes, to vocational purposes. The aspect selected should possess the following qualifications:

1. It should be an aspect that gives a comprehensive view of the power plant as a thing in itself and in its relations to modern civilization.

2. It should be an aspect that will appeal to the student's instinct of wonder and lead to an appreciation of the great problem of modern science, namely, to gain control of the forces of nature.

3. This aspect should be one appealing at once to the student's as yet largely undeveloped interest in the subject. It should begin by presenting engineering as a possible life purpose that he may make his own, through its appeal to his fundamental instinct.

4. It should be an aspect of the plant that would stimulate interest in its anatomy and prepare for laboratory work, in which the student dismantles apparatus and machinery with a view to becoming acquainted with its construction.

5. It should be an aspect having a profound scientific meaning and interest, capable of leading immediately to the most fundamental scientific aspects of the subject.

6. It should lead to an immediate achievement in the way of insight into the design or operation of the plant, so far as this one aspect of it is concerned. It should develop immediately definite problems taxing the student's intensive effort.

7. It should be an aspect replete with relations to the history of physical science and the triumphs of scientific processes applied to the conquest of nature's resources for the service of men.

By selecting such an aspect of engineering science and practice it will be possible to start the student at once along practical, theoretical, technical, scientific and cultural lines of development in the freshman and the sophomore years. As much practical work may be given as the student finds time to handle. On such a scheme enough practical work may be given to permit his spending his vacation profitably in work preparing him for his future profession. In centers where the coöperative system is a possibility the practical side of the work can be carried far. Some students will demand more practical work than cultural. On such a scheme as this it will be possible to differentiate the course in practical, scientific and cultural directions in the interest of different groups of students. The cultural and purely scientific aspects of the freshman and sophomore years may make such an appeal to some students that they may care to continue this

side of their education for two more years in a preparatory arts course, before beginning the junior and senior engineering work. Others will end the freshman and sophomore years as "intelligent artisans," to use Professor Karapetoff's phrase. In other words, the work of these two years will be thoroughly organized in the interest of vocational choice and direction. In making life purposes the basis of the reasoning process such an organization of courses is inevitable.

It is not possible in a short paper to enter into the details of such a plan but some light on its feasibility is desirable. If we should analyze our educational material into "elements" we should find each element of it related in innumerable ways to every other element. Therefore, the way in which they are combined at present is not an inevitable one. Make these elementary ideas *nascent,* to use a chemist's phrase, and innumerable other combinations of them are possible, besides the one represented in our present organization of them.

There is no trouble in selecting for the beginning aspect one like that described above. The only question is, will we be obliged to take too much for granted in the preparation of the student?

This last is an imaginary difficulty due to two peculiarities of our own training. First, we think that we must start with definitions complete from a scientific point of view. Now this idea is right in just one particular. Modern educational science demands that in no part of the course shall methods be taught or habits developed that must be revised later. The student from the start should acquire habits of action and thought that will not need later revision. This requirement is not incompatible with definitions at first that do not reveal the whole content of a concept. But no definition should be given that has to be *revised.* It may be enlarged as the work goes on. A more fundamental meaning of a concept may be reached. The earliest definition of "force" does not need to reveal the fullness of meaning that the con-

cept has in the mind of the most critical-minded physicist. The sophomore is not critically minded. At the same time the earlier definition should contain nothing incompatible with the later one. The most highly trained physicists are gaining enlarged outlooks with every advance of their science. Why should not the student's outlook enlarge as he progresses? Enlargement of outlook does not mean revolution of his whole system of ideas and habits. In science the final word should never be spoken about anything. Many scientific men fail to understand this fundamental spirit of science. If we give up our striving for finality in our definitions and demonstrations the difficulties of carrying out the ideas of this paper disappear. This striving for finality is scientific heresy and it does no end of damage to the victims of our present shortcomings. A man who has been very successful in directing industrial research tells me that he prefers men trained in pure science to technical graduates in the prosecution of this kind of work. The technical men believe that the only way to do a thing is the way they have been taught. When industry wants to accomplish a certain end these men find plenty of reasons in their science why the thing is impossible. Now, science has never been fortunate in its denials. Its power has been in its affirmations. These men have learned their science as a closed system. The auxiliary sciences, physics, chemistry and mathematics, have a larger work to do in technical education than they are now doing. The principles of physics should first appear as instrumentalities for solving fundamental engineering problems. Later, should rise questions of improving these instrumentalities. This means an interest in physics as a pure science, not as a static science, but as one in the process of development and ever making fertile contributions to engineering. A critical study of the foundation of this science is too difficult for the beginning. But as a critical interest grows, even the engineering student may become quite concerned with the theory involved in the absolute measurements of electrical quantities and in many other fields of theoretical physics.

But at first, unit poles, unit fields, or absolute definition of current are better left out.

In the second place the first acquaintance with electrical instruments and electrical machinery should be in the way of finding out what they will *do* rather than what they *are*. A man may know what a watch will do without knowing much about the structure and the function of its works. He may perform experiments that will tell him satisfactorily what an ammeter and a voltmeter will do without any knowledge of their internal structure.

Regard for these two sources of prejudices arising from our own training will remove the difficulties of the plan here sketched out. All men are in ruts of some kind. It is difficult even to realize it in our own case, but we owe it to engineering education to locate our own.

THE EDUCATION OF THE FUTURE ENGINEER.

C. L. CORY,

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An education is an achievement, not a gift. It can be neither inherited nor bequeathed. Fortunately there is only one way to get it. One must work for it and continue working to keep it.

Education means development, growth, evolution, discovering one's self. It is impossible for one to do until he knows. It is, however, infinitely more important to do than to know. It is possible for the athlete to develop physically by living naturally and constantly exercising. In order to continue being an athlete, however, he must not only continue to live naturally and temperately, but must also continue to exercise his body and keep not only it but his brain under control.

With the mind it is much the same. Once trained it also must be used, exercised, and, like the athlete's body, must be ready upon demand to rise to a supreme effort. Mediocre endeavor stifles progress. The constructive, creative mind must work in order to achieve.

The man is best educated who is most useful, the most capable of service. An engineer is one "competent to conceive, devise and organize the directing of the forces of nature to the use and convenience of man."*

The systematic, organized education of engineers in this country has now continued uninterruptedly for approximately a third of a century, almost exclusively in schools and colleges of university rank. The membership of this Society consists almost exclusively of men intimately connected with the work of educating young men who have the ambition to become

* Prof. D. C. Jackson, Proceedings American Institute of Electrical Engineers, 30th Annual Convention, Cooperstown New York, June, 1913.

engineers, and a very large part of the present members have first been students, and later teachers, of engineering during a large portion of this entire period.

From an academic and theoretical standpoint many features of such work have been discussed more than once during these years, all having directly or indirectly to do with the formulating of the curricula or courses of study best suited for the training of engineers. The number of graduates from the engineering departments of American universities and colleges has now become sufficiently large to justify analysis leading to conclusions that can not be misleading. Also, the number of engineering students and graduates in the United States has become less during the past few years, so that a bench mark, so to speak, or point of inflection on the curve has been passed.

No one can, with truth, deny that considerable success has crowned the efforts of engineering educators to date. However, political, economic and financial conditions have changed in recent years and are undergoing even greater and more rapid changes at the present time, and if the engineer is going to continue his useful and effective service to mankind he must not be oblivious to the changed conditions, but must carefully and seriously compare the present with the past in relation to the work of the engineer so as to most wisely plan for the future.

It is therefore not only worth while, but quite necessary, to now concern ourselves from an academic as well as a practical standpoint with the next or future period of engineering education.

During the life of engineering training as such there have been made a myriad of inventions having to do with steam, electricity and the transmission of intelligence, every one of which has rendered possible, and as a result demanded, the expansion of man's energy and opportunities. During the same period there have been enacted almost innumerable laws having for their purpose and avowed object the restriction

and control of man's initiative effort and energy. Necessity has forced, and the prospects of reward have encouraged, economic transformations and readjustments so that the *rate* of living is greater today than ever before in the world's history. Business transactions are consummated, very large and important schemes are planned and many kinds of social intercourse are carried on even across the continent by the use of the modern telephone. The needs of the day require the most able, loyal and wise cooperation to meet the exigencies which arise. More is constantly expected of the individual, whether he be leader or follower, the race is swifter, and real laurels are denied to all but the especially strong.

The responsibility of caring for himself is always a necessary factor in man's evolution, but it is more necessary today than ever before. Isolation from the world to prepare for the world's work is now held to be an error. Man is equipped for a life of usefulness by qualities, not as a result of the mental possession of facts. The institution that best helps to develop the most desirable qualities and the best type of character, not the one that imparts the most information, will in future be known as the successful and superior college or university.

To fully and completely analyze the present, and especially the future, economic, financial, social and engineering problems, men must be trained to observe, think logically and constructively, and act decisively, just as the athletes are trained to have strong, active and efficient bodies.

Are the men who have been educated at the engineering schools of this country doing as much as might reasonably be expected of them in this broader field, remembering that capable and wise men are few and far between? Do university trained men of the engineering profession contribute a fair share of the leaders and wise men possessing alert yet sound judgment? The answer, it is to be regretted, must be in the negative. Rapid as has been the perfection and utilization of scientific and engineering devices, very few college trained

technical men have risen to the demands of the occasion, to, in the most economic and satisfactory manner, plan for the community's largest interest. Leaders and organizers, often trained in the practical school of experience, have for the most part been in supreme command, while very often practically their entire staff of assistants have been engineers with a college diploma.

There are notable exceptions, and of course it is unreasonable to expect all young men who succeed in completing a college course to ultimately qualify for leading positions of administration and direction. Nevertheless, it seems patent that, considering their superior advantages and opportunities, technically trained men have fallen far short of what might very properly have been expected of them. What is of infinitely more importance, however, is, that if present indications are not misleading, there is every reason to believe that in the next two or three decades a decidedly less percentage of the total number of technical graduates will achieve positions of service calling for great administrative ability and superior leadership.

While supporting this view I will also hope to make some observations and suggestions that may be found more constructive than critical.

It is first necessary to clearly outline what to me seem the primary objects of either a four or five year undergraduate course in engineering. Having outlined the desired result, I shall indicate some changes in the present engineering courses, more in spirit than in detail, in presentation than in content, which may tend toward securing those results.

It is to be assumed that the young men entering college will be of an average age of eighteen years so that ordinarily they will complete the undergraduate course by the time they are twenty-two. Before entering college they are supposed to have graduated from or completed the equivalent of the work given in, the ordinary high school. They should be prepared to successfully undertake the courses in the freshman or first

year of any one of the many American engineering schools. I should prefer that they enter with a modern language, because it is my experience that it is very much easier for a young man to obtain a grasp of a foreign language before entering the university than during the freshman or any other year in college, at a time when his main interests are devoted to the fundamental and applied courses in the engineering curricula.

I feel strongly that the main objects of an engineering or indeed any other course worth while in one of our universities are not so much to impart information as to train the mind, to teach underlying principles, to impress ideals of high standards, to insist on personal efficiency, to spur to superlative effort and to encourage broad leadership. Industry, accuracy and painstaking, serious work are obviously essentials. Clean living and wholesome companions are of more importance today than ever before, and yet while at most of our colleges and universities cigarettes, alcohol and automobiles are optional, a stranger on seeing the devotion of many of the students to them would surely suppose them all to be rigidly prescribed courses.

I am not unmindful of the lack of preparation and the limitations of the average college student about twenty years old. Very few have had any serious mental training and even fewer know how to study, which results in a general tendency toward imitation. The majority of engineering students have little or no ability to express their ideas in correct, clear and forceful language, either written or spoken. Students find many distractions from serious study. College activities are more than merely worth while. For three years the senior, or final, year of student days is very properly looked forward to as the time when not only the most important courses will be undertaken, but also when the heaviest responsibilities come in all student affairs, student government, college publications, athletics, social functions, and with engineering students

the necessity of completing a thesis and usually the securing of a position after graduation.

The four years in college may profitably be compared to a life. In both one may get a superficial start on account of some real or apparent pull or influence, but in both, the one who really has it in him, independent of his family, friends or social position, will come out really successful. If a young man goes to college and there makes good in the right sense it certainly encourages the hope that he will do the same in the larger game of life. As a student he himself must do the work, but his teachers have a large responsibility, particularly to first prevent his losing his sense of proportion as between his university work and his student life, and second, to assist in his gaining a broad viewpoint and establish the proper relationship and continuity between his several university courses.

It is my firm conviction that throughout the entire four years every student in every course should get something of more importance than the content of the course itself, should have every subject presented in such a manner that its relationship to all other courses of instruction is made clear, be warned of the result of attempting to become a mediocre specialist in narrow fields of endeavor, and above all, be urged and inspired to strive, in college and out in the world, to obtain that broad foundation and viewpoint which is so necessary to leadership in the affairs of life.

There are two oriental maxims which translated are:—

> "It is the parent who has borne me; it is the teacher who makes me man."
>
> "Thy father and mother are like heaven and earth; thy teacher and thy lord are like sun and moon."

Here we are the crux of the problem.

"It is the teacher and not the subject or the equipment or buildings and apparatus that makes the enduring institution; but until teaching is unified to a much greater degree we shall

fail to attain that degree of educational efficiency which will enable us to reach the limit of our ideal.'"*

What types of men are to be found on the staff of instruction in the engineering departments of American institutions? I have presumed to classify them into three separate groups:

I. The theoretical engineer who in reality is not an engineer at all. For the most part he teaches out of books and is neither to any great degree an original scientist nor an original thinker. His status in the academic world is reasonably well established but usually he is practically unknown in the broad field of real engineering and academic achievement. He faithfully and conscientiously does his work, although he has no conception of the continued consistent endeavor, at high speed, which is demanded of his colleagues not within the academic sphere. In universities he is the hewer of wood and the drawer of water.

II. The applied scientist who is an original thinker and an investigator, who has done—sometimes much, sometimes little—research work of considerable scientific and engineering importance. He is not necessarily what is generally called a good teacher, but is of a creative type, his work being known and appreciated in the scientific and engineering world.

III. The real engineer, who can design, create and interpret, and who has that broad concept of life which enables him to adapt and organize the forces of nature efficiently and effectively to the service of his fellows. He is a leader and administrator, has executive ability, and his work includes consideration of money expenditures, which is one of the basic features of engineering practice, but has little, if anything, to do with either pure or applied science. He lives in the world of extraordinary endeavor, has knowledge first hand of the details and economics of his profession, is capable of clearly distinguishing between engineering and financial difficulties, and fully appreciates the value of time.

* Presidential address of Dean Gardner C. Anthony, Society for the Promotion of Engineering Education, Princeton, June, 1914.

All real executives are of necessity good teachers. Unfortunately, for proper reasons perhaps, there are relatively fewer teachers of the third class in our engineering institutions than is desirable. There would not be as many as there are had not the administrative heads of many engineering schools begun some years ago to permit such men to do what is generally termed "outside work." The wise and proper provision should be made, however, that the outside work should be beneficial to both the institution and the instructor.

It is not my purpose to suggest any material modification of the content of the present curricula of engineering courses, to advocate a five instead of a four year course, or to urge that an A.B. degree should be required for entrance to what would then be definitely a professional or graduate school of engineering. I believe in maintaining at least present standards of admission, but do not deem it wise to place in the path of all what would be for many an insurmountable obstacle to obtain that kind of an education best suited to many young American boys. I would, however, materially change many of the courses now given in all of the four years. If I had a son and it were impossible for him to acquire a trained, systematic and organized mind and achieve mental and judicial poise in any other manner, I would not object to his being taught mathematics practically exclusively for four years, not for the knowledge he might acquire or the subject, nor even for the mental discipline ordinarily supposed to result from a thorough mathematical study, but that he might in the end appreciate that mathematics may best be utilized as a method of logic, as a means to an end rather than as an end in itself, and to secure his using its processes, logically interspersed among conclusions, even when these of necessity must essentially be in the nature of compromises.

No single course or group of courses should be expounded without the most painstaking effort being made to bring out their applications and especially their limitations in the real issues of life. It is even more important to impress upon

students the inter-relation of all courses in the curriculum, that no one subject should be held unduly important, but that the entire course of study as a whole becomes, as it were, a part of the students themselves. Then the graduates should be well on the way toward the ability to "direct the forces of nature to the use and convenience of man."

Those in responsible charge of the instruction in engineering in our American institutions can not but be impressed with the splendid development of agricultural education in recent years. Now our schools and colleges of agriculture are attracting a great many students. In the earlier years agricultural education was more scientific than practical, more academic and theoretical than instructional, especially as far as the undergraduate students were concerned.

Partly as a result of the earlier work in the various departments of agriculture in the state institutions of the country, but also because of a decided economic change in the relation of agriculture to other wealth production, we find the present extensive and sound development in agriculture not only in our universities, but in the country in general.

There is a certain parallel between engineering and agricultural instruction and engineering and agricultural development. Many of the members of this Society will probably, as students, remember most vividly the entire lack of mutual interest between engineering and agriculture. There is now, however, a very definite inter-relationship between the two, and in the years to come the work of many engineers will be required in the service of those in charge of extensive agricultural developments. The most constructive and effective work will result if our universities succeed in turning out engineering and agricultural graduates with the ability to conceive and direct all the forces that must work in harmony in order to accomplish the most desirable results for the benefit of the people of this country.

Instruction in agriculture undoubtedly is more directly in touch with the lives of the people than is the corresponding

work in engineering. Individuals carry on the practical work of agriculture, while for the most part great organizations are required to accomplish important engineering feats, and it probably will be found that considerable modification will be necessary in agricultural instruction before it may be said to have become as standardized as that of engineering at the present day.

The recent introduction of practical courses in agriculture accompanied by the great increase in the number of agricultural students, indicates to my mind the necessity of critically examining our present courses of engineering instruction to the end that they may accomplish the most desirable results. Agricultural development in the immediate future demands a large number of college trained men, just as the engineering industries have been greatly benefitted by engineering graduates during the past twenty-five years. But the kind of a college trained engineer that is in most demand today is a much more able man than formerly. In life's endeavor the competition between college trained engineers is now much more keen than in the early days of engineering education.

I repeat that I am not advocating material or radical changes in the present curricula of engineering schools, nor do I wish to be understood as maintaining that a large percentage of our graduates can be made into leaders and men of large affairs. I do maintain, however, that a much too large proportion of engineering graduates, after being as many as ten years out of college, find themselves definitely and permanently diverted into narrow fields of endeavor, and to the end of their days will in all probability be working continuously in doing routine work which, while such may be engineering, will need an adjective ahead of the word "engineering" in order to indicate its extreme limitations.

It seems to have been necessary to bring into use these adjectives, that have been now largely introduced as a prefix to the word "engineering," even down into our four-year engineering courses in order to more definitely designate the kind

of an engineer we are trying to develop. These adjectives are so numerous that I have no ambition to be known as the originator of a new one, but I am interested, however, in the development of a type of engineering graduate who is first of all a thinker and organizer and an administrator, but under and throughout it all a clear-headed engineer, not only in technical but in economic and financial matters.

Detailed, first-hand knowledge must be gained in the most modest, painstaking manner in the earlier years after leaving college before the technical graduate may become an engineer, but he should receive, and take from, his alma mater lessons well learned in methods of study and mental processes, and in addition a full realization of the fact that to be of the greatest loyal service to his fellowman it is incumbent upon him to organize and administer not only with technical knowledge but also understanding fully the financial and economic relations of engineering work to mankind.

In trying to do this for our young men it would be a backward step to introduce additional and more specialized courses into our already much adjectived engineering curricula. It is necessary, however, for teachers of engineering to constantly impress upon students that the greatest opportunities for the majority of them, except the most gifted creative minds, are inseparably connected with the hardest concentrated work, and the most valuable service they can render others will require leadership, administrative ability, and a combination of character, technical skill and sound judgment.

DETERMINING THE EQUATION OF A CURVE.

BY WINSLOW H. HERSCHEL,

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Every freshman knows how to plot or graph the equation of a curve, but the reverse process of finding the equation when a series of points has been experimentally determined is less generally known. Yet this is a very important problem in research work, since by an equation as much information may be given as by a whole table of figures, and in a form more suitable for purposes of interpolation.

Just as we must first differentiate in order to collect material for a table of integrals, so we must plot and study curves preparatory to recognizing the different types of curves from their graphs. Then, when the type of curve has been discovered, the second part of the process consists in determining the constants of the individual curve which distinguish it from other curves of the same general type. Graphs of curves of almost infinite variety, which are known to mathematicians, may be seen in books on curve tracing, as for example in the one by Percival Frost, but fortunately the great majority of physical laws conform to curves of comparatively few types.

Curves may be continuous or periodic, the latter being those that run a certain length with a certain form, and then this shape is repeated just as in a wall paper pattern. Such curves are very important in electrical work, but they belong to a class by themselves and will not be here considered. Continuous curves, with the exception of closed curves like the circle and the ellipse, have a value of Y, or of $\pm Y$, corresponding to every possible value of X from zero to infinity, if the curve passes through the origin. For the simpler curves with which we have to deal it is most convenient to use rectangular coördinates, the equation for the horizontal X axis being $Y=0$, and for the vertical Y axis, $X=0$.

The Straight Line.

The straight line, a curve with infinite radius, is very important, not only because so many natural laws have a linear equation, but also because equations that are not obviously linear may, by one device or another, be put in that form in order to simplify the work of finding the constants. The general form of a linear equation is $y = a + bx$ (Eq. 1) in which a and b are constants and x and y variables. If $x = 0$, $y = a$, which shows that the line will cut the Y axis at a distance a from the origin. Therefore a may be determined by prolonging our straight line until it cuts the Y axis, and noting the distance of this point of intersection from the origin of coördinates. On the other hand, if $a = 0$, then $b = y/x$ which is the constant tangent of the angle between our straight line and the X axis. Therefore the value of b may be obtained by taking the difference between any two values of y and dividing it by the difference between the two corresponding values of x. If the line passes through the origin, any one value of y divided by the corresponding value of x will give the same result. It should be noted that a merely produces a change in the vertical position of the line, without changing its slope. In general, if $y = a + fx$, where fx signifies any function of x, a merely moves the curve up or down without changing its form in the slightest, and its value may be obtained by letting $X = 0$. If $a = 0$, the curve passes through the origin.

The graph of a straight line is a very convenient substitute for a conversion table, having the advantage, as compared with a slide rule, that it may be easily and quickly constructed to read to any number of significant figures desired. The graph need not be large if the range of values is small, even though a large number of significant figures is desired.

$p = 0.434\ h$, the equation which shows the relation between pressure in lbs. per square inch, and depth of water in feet, is in the form $y = bx$, and as an example of the complete Eq. 1 we have $W = 1.10 + 2.670\ x =$ weight of a 1″ bolt, x being

its length measured under the head, and 1.10 being the weight of the nut and head.

When a series of points have been determined experimentally and it is known or assumed that the curve that will best fit these points is of the linear form, there are several ways by which the position or the equation of the line may be found.

(*A*) A stretched black thread or the edge of a transparent triangle may be placed so that about half the points lie on each side of it, and so as to follow what appears to the eye to be the general trend of the points. The disadvantage of this method is that no two experimenters would locate the line in the same position, or obtain the same equation from the same series of points.

(*B*) A second method which may be used whenever the line passes through the origin or any other known point, is to determine a second point whose abscissa is the average of all valus of x and whose ordinate is the average of all values of y. The line is then completely determined since two points are known.

(*C*) A more general and exact method, in which the following equations are used, is called the method of least squares.

$$a = \frac{\Sigma x^2 \Sigma y - \Sigma x \Sigma xy}{n\Sigma x^2 - \Sigma x \Sigma x} \qquad \text{(Eq. 2)},$$

$$b = \frac{n\Sigma xy - \Sigma x \Sigma y}{n\Sigma x^2 - \Sigma x \Sigma x} \qquad \text{(Eq. 3)}.$$

(*D*) In case $a = 0$, Eq. 2 may be dispensed with, and Eq. 3 becomes

$$b = \frac{\Sigma xy}{\Sigma x^2} \qquad \text{(Eq. 4)}.$$

To illustrate these last three methods, we shall assume that tests have been made on a spring in compression, and that for loads given in Col. *X*, the length of spring varies as in Col. *Y*. Deflections are given in Table 1 under the heading y, and the other columns contain functions of *X*, *Y* and y

which occur in Eqs. 2 and 3. n = number of points plotted, and for the present case is equal to 10.

TABLE I.

X	X^2	Y	XY	y	Xy
0	0	10.5	0	0	0
11	121	9.9	108.9	0.6	6.6
16	256	9.0	144.0	1.5	24.0
26	676	8.6	223.6	1.9	49.4
31	961	7.8	241.8	2.7	83.7
37	1,369	6.9	255.3	3.6	133.2
44	1,936	6.5	286.0	4.0	176.0
51	2,601	6.2	316.2	4.3	219.3
58	3,364	4.7	272.6	5.8	336.4
67	4,489	4.5	301.5	6.0	402.0
341	15,773	74.6	2,149.9	30.4	1,430.6

By method (B) the line will pass through the points $X=0$, $Y=10.5$ and (34.1, 7.46) so that when $X=0$, $Y=10.5=a$. To make $a=0$, we must change our origin to the point (0, 10.5) which changes our other point to (34.1, —3.04) so that the tangent of slope is $-3.04/34.1=-.0892X$. The minus value of b shows that the line lies in the 2d and 4th quadrants. If we use y instead of Y, $a=0$ and $b=3.04/34.1=+.0892$, giving the simpler equation, $y=.0892X$.

By method (D), $b=1{,}430.6/15{,}773=0.0906$, using the deflection y for the ordinate, in order that our curve may pass through the origin. With method (C) we may use either length Y or deflection y. From the former we have

$$b=\frac{10\times 2{,}149.9-341\times 74.6}{10\times 15{,}773-341\times 341}=-0.0940,$$

$$a=\frac{15{,}773\times 74.6-341\times 2{,}149.9}{10\times 15{,}773-341\times 341}=+10.71.$$

Using y we have:

$$b=\frac{10\times 1{,}430.6-341\times 30.4}{10\times 15{,}773-341\times 341}=+0.0948,$$

$$a=\frac{15{,}773\times 30.4-341\times 1{,}430.6}{10\times 15{,}773-341\times 341}=-0.241.$$

We may check the accuracy of the mathematical work by showing that the equations $Y = 10.71 - .0940X$ and $y = -.241 + .0948X$ give the same result. For example, if $X = 100$, the former equation gives $Y = 1.31$ or $y = 10.50 - 1.31 = 9.19$, while the latter equation gives the deflection directly as $y = 9.48 - .24 = 9.24$, which is a close enough check on 9.19 for slide rule work. In Fig. 1, showing graphs of the equations which we have calculated, the lines are marked with letters indicating the method by which they were obtained. It should be noted that by method (D) we avoid the labor of finding ΣX, ΣY and a, and the work of finding b is simplified. It is therefore highly desirable to so conduct experiments or select the variables that the curve will pass through the origin. In "An Introduction to the Theory of Statistics," p. 177, G. Udny Yule gives an example of this in determining equations of the lines of regression. While the introduction of coefficients with which we are not concerned somewhat complicates his method, it is essentially what we have called method (D) and his equation for "b_2" reduces to our Eq. 4. Unless there is a very good reason for believing that the curve passes through the origin, method (C) should be used in preference to (D) because the curve thus obtained will fit the points better, as shown in Fig. 1.

The use of logarithms in order to make an equation take the linear form will be considered later, but we may here review a few other devices. $y = \frac{cx}{x+d}$ is the equation of an equilateral hyperbola, and may be written, $1/y = 1/c + d/cx$ or $v = a + bu$ which has the same form as Eq. 1. d/c and $1/c$ correspond respectively to a and b and may be found in the same way. If values of $1/y$ are plotted against values of $1/x$ and the resulting graph is a straight line, it shows that this equation applies to the case at hand.

In Fig. 2 are shown curves of this form for problems No. 2, 3, and 4, data for which are given in Table II.

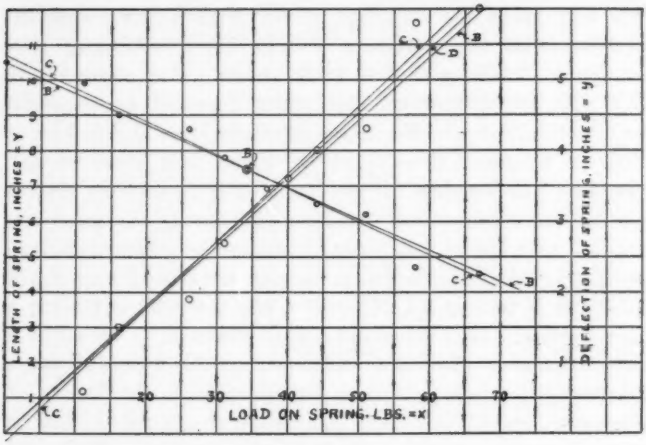

FIG. 1

TABLE II.

Problem 2.

x	y	$u=1/x$	$v=1/y$	a	b	c	d
1.0	0.8	1.000	1.25				
1.7	1.2	.588	.833				
1.9	1.3	.526	.769				
2.3	1.5	.435	.667				
3.0	1.8	.333	.556				
4.3	2.1	.233	.476				
6.0	2.4	.167	.417	0.24	1.01	4.16	4.20
			Problem 3.				
0.84	10.92	1.19	.092				
1.24	3.64	.806	.274				
2.00	2.38	.500	.42				
3.34	1.96	.300	.51				
5.00	1.82	.200	.55				
6.67	1.68	.150	.595	.655	−.475	1.53	−.725
			Problem 4.				
1.3	14.1	.77	.071				
2.4	18.8	.42	.053				
3.6	21.2	.28	.047				
4.9	22.7	.20	·044				
6.7	24.0	.15	·041	.034	−.0475	29.4	1.40

The values of a and b were found graphically as shown in Fig. 3, and c and d were calculated from these values. In each of the three cases, which are from "Treatise on Graphs," by Geo. A. Gibson, the curves are asymptotic to the lines $x=-d$ and $y=c$, and by changing the origin so that the axes of coördinates and asymptotes become identical, the equations are reduced to the simpler form, $xy=\text{constant}=1/2\ p^2$ where p is half the parameter, and is also equal to the distance from the

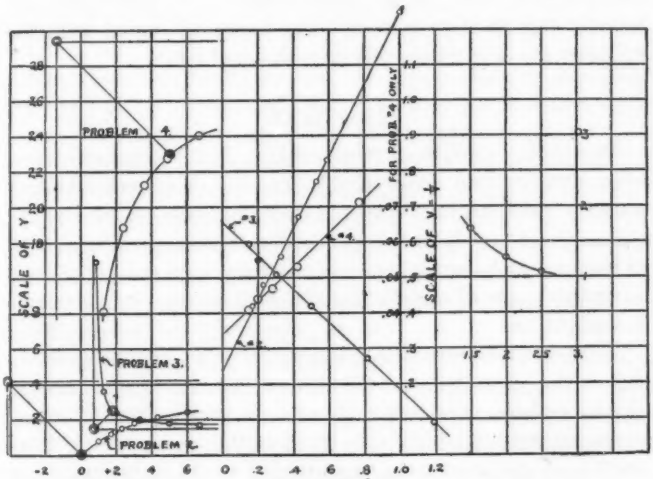

FIG. 2 FIG. 3 FIG. 4

apex to the intersection of the asymptotes at the origin. Thus in problem 2 let $X=x+4.20$ and $Y=y-4.16$. Then the equation for the curve, which we have found to be

$$y=(4.16\,x)/(x+4.20),$$

becomes

$$Y+4.16=(4.16(X-4.20))/X$$

from which $XY=17.3$ and $p=5.9$. Similarly in problem

3, $XY=1.11$, $p=1.49$ and in problem 4, $XY=41.2$, $p=9.1$. In Fig. 2 the asymptotes have been located from the calculated values of c and d, and the lengths p are indicated by concentric circles.

If the equation of a curve is known, its constants may sometimes be determined very simply. Thus if $y=ax^2$ then $y/x^2=a=$a constant, and we need only find the average value of y/x^2 or plot y against x^2 and find the slope of the resulting straight line which gives us the value of a. But more frequently the problem is to find the values of a and n in the equation $y=ax^n$ which will be considered later.

The Circle.

The circle, considered mechanically, is the simplest curve, even simpler than the straight line, for in all straight line motions which actually generate a straight line (in contrast to rulers which merely enable the draftsman to copy a line which is assumed to be straight) it is necessary that one point shall move in the arc of a circle in order that another may describe a straight line.

A circle whose center is at the point (a, b) has the equation $(x-a)^2+(y-b)^2=r^2$ (Eq. 5). There are three constants in the equation, and hence if we take three values of x and corresponding values of y, and substitute them in Eq. 5 we shall have three equations from which to determine three unknown quantities. If more than three points were utilized in this method, there would be a different solution for each set of three points. Prof. Karl Pearson has, however, succeeded by what he calls the method of false position* in finding with great accuracy the circle of closest fit to a series of points. Five points were used in the illustration, but Prof. Pearson remarks, "The labor would not have been much greater had we required a circle (or any other three-constant curve) through even a dozen points."

* *Philosophical Magazine*, June, 1903, p. 658.

We may assume the three points shown in Fig. 4, with the following coördinates:

x.	y.
1.5	1.68
2.0	1.27
2.5	1.06

Then the three simultaneous equations obtained from Eq. 5 are

$$(1.5-a)^2+(1.68-b)^2=r^2,$$
$$(2.0-a)^2+(1.27-b)^2=r^2,$$
$$(2.5-a)^2+(1.06-b)^2=r^2.$$

From these equations we find, by plain algebra, $a=3.04$, $b=3.05$ and $r=2.06$, and the arc in Fig. 4 was drawn with the center located by a and b and with a radius r.

This indicates the general purely mathematical method of finding the constants when the equation is known and the points are assumed to lie exactly on the curve. It has the disadvantage of being laborious and of neither helping to determine the proper equation for the curve at hand, nor of fitting the best curve possible to a series of points which do not lie exactly on any regular curve.

In the case of a circle the easy graphical method of locating the center is to find the intersection of perpendiculars erected at the centers of any two chords. The center square of the machine shop, on the other hand, depends on the principle that the bisector of the angle between two tangents will pass through the center.

The Ellipse.

The equation for an ellipse, with the origin at the center, is $x^2/a^2+y^2/b^2=1$ (Eq. 6) and it is easily seen that if $a=b$ this reduces to the equation of a circle with a radius equal to $a=b$. But if a is greater than b, then $2a=$ the major axis (which has the direction of the X axis) and $2b=$ the minor axis of the ellipse. Elliptical holes have very often to be cut in boiler plates, and it might be important in the case of interchangeable parts, to know whether the holes were cut true to

shape, as with a modified elliptic chuck, or whether the ellipses were false or approximate ellipses, chipped out by hand It is comparatively easy to test the correctness of an ellipse if the whole figure is at hand. If we swing an arc with radius a and center at an end of the minor axis, this arc will cut the major axis at points called the foci, shown at F in Fig. 5.

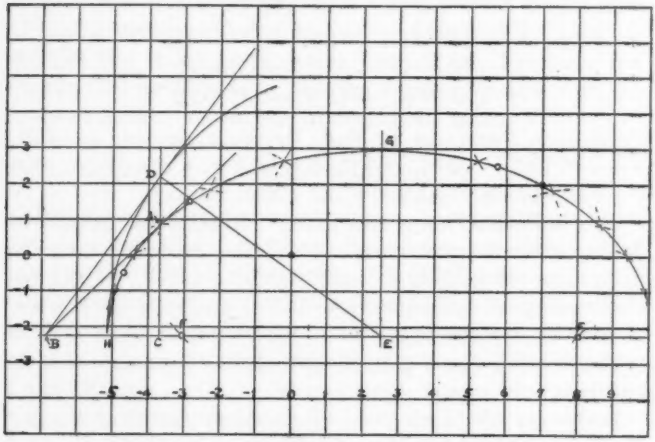

FIG. 5.

The sum of the distances from any point on the curve to the foci is equal to $2a$. But with only a portion of an ellipse at hand it might be taken for some other curve, as a parabola or hyperbola. It may be distinguished from these curves by plotting on logarithmic paper, since they would then appear as straight lines, while an ellipse or a circle would give a curved graph.

If we have less than a quadrant of an ellipse we may find the equation either analytically or graphically If the center of the ellipse is at the point (c, d) Eq. 6 becomes

$$\frac{(x-c)^2}{a^2}+\frac{(y-d)^2}{b^2}=1 \text{ (Eq. 7).}$$

As Eq. 7 contains four constants or unknown quantities, we must select four points giving values of x and the corresponding values of y. Let us take the following values:

x.	y.
-4.70	-0.50
-2.85	$+1.50$
$+7.00$	$+2.00$
$+5.78$	$+2.50$

By substituting these values in Eq. 7 and solving the resulting four simultaneous equations, we find, $c=2.50$, $d=2.24$, $a=7.65$ and $b=5.25$. The elliptical arc shown in Fig. 5 was drawn from these values.

To solve the problem graphically, suppose a tangent drawn

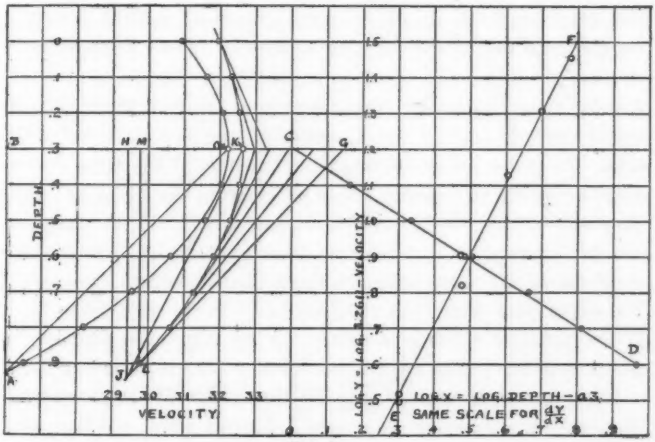

FIG. 6

at any point A on an ellipse and intersecting the major axis at B. From A drop a perpendicular to the major axis at C. Then if D is the point where the circumscribing circle intersects the line CA, prolonged, BD will be the tangent to this circle. Therefore, if E is the center of the ellipse, and H is

an end of the major axis, $DE = HE = HC + CE$; $CD^2 = DE^2 - CE^2 = (HC + CE)^2 - CE^2 = HC^2 + (2HC)CE$. But CD is a mean proportional between BC and CE, so $BC(CE) = HC^2 + 2HC(CE)$, from which $CE = HC^2/(BC - 2HC)$ the right-hand side of which equation contains only two quantities, both of which may be scaled from the figure. $CE + HC = a =$ half the major axis, while $b =$ half the minor axis, may be found from the fact that $a/b = CD/AC$. In our case $CE = 1.45^2/(3.20 - 2.90) = 7.00$ to check 6.20. It will be seen that $BC - 2HC$ is such a small quantity that a slight inaccuracy in reading lengths will make a large error in the value of CE and hence in HE. We should have checked 6.20 exactly if we had read $BC = 3.238$.

The analytical method is tedious and time-consuming. On the other hand the objection to the graphical method is that a tangent can not be drawn with accuracy. Prof. John Perry* emphasizes this point when he says, "Many impractical rules will be found in books, requiring us to draw a tangent to a given curve at a given point, or to find the curvature there by trial. If half a dozen students get tracings of the same curve, and two points to measure the angle between the tangents there, they will obtain six very different answers." If we compare one trial analytically with one trial graphically, the former is of course the more accurate (provided no errors are made) but experience with both methods leads to the conclusion that if the amount of time necessary for an algebraic solution is devoted to successive approximations by the graphical method, a fairly accurate answer may be obtained. The best method to use in a particular case would depend upon whether one had at hand a few isolated points, suitable for the algebraic method, or a sufficient number of points so that a curve could be drawn through them with fair accuracy.

* "Applied Mechanics," p. 23.

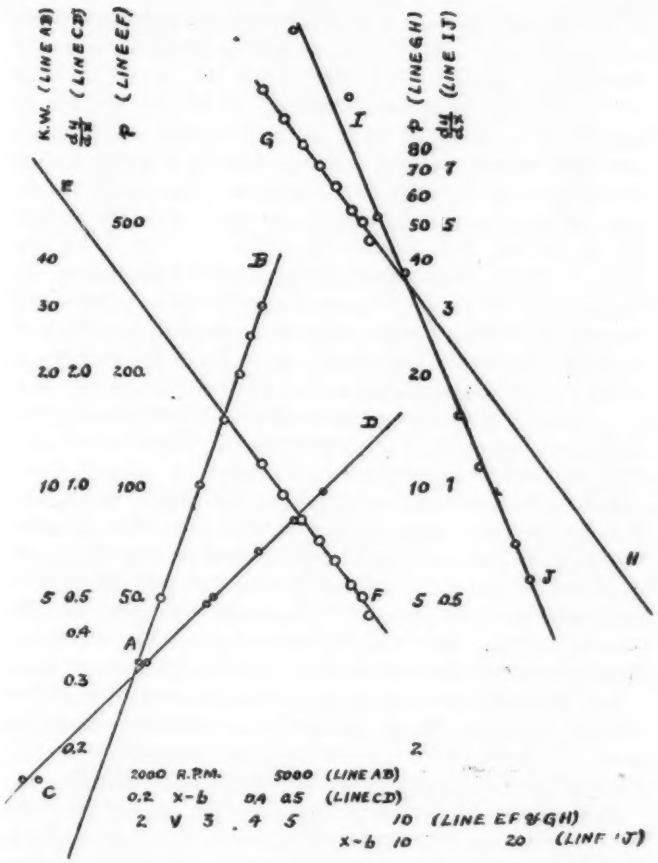
K.W. (LINE AB)
dy/dx (LINE CD)
P (LINE EF)
P (LINE GH)
dy/dx (LINE IJ)
E
40
30
2.0 2.0
10 1.0
5 0.5
0.4
0.3
0.2
500
200
100
50
B
A
C
D
F
G
I
80 7
70
60
50 5
40
3
20
10 1
5 0.5
2
H
J
2000 R.P.M.
5000 (LINE AB)
0.2 x-b 0.4 0.5 (LINE CD)
2 V 3 4 5
10 (LINE EF & GH)
x-b 10
20 (LINE IJ)

FIG. 7

The Parabola.

The general equation of a conic parabola may be written, $y = a + bx + cx^2$ (Eq. 8). As previously noted, the a merely changes the position of the figure, and this is also the case with b, though this is not so evident. If we take the simple equation of a parabola, lying in the first and second quadrants and concave upward, a minus value of y giving the inverted figure in the other two quadrants. The more common form of equation, $y^2 = 2px$, brings the parabola in the 1st and 4th quadrants. The greater the value of c in Eq. 9, the sharper will be the bend at the apex. By a change of the vertical scale, the graph of $y = x^2$ may be made to represent $y = cx^2$, the necessary scale being determined by the value of c. If the vertex is at the point (q, r) Eq. 9 becomes $y - q = c(x - r)^2$ or $y = q + cx^2 - 2cxr + cr^2 = (q + cr^2) - 2crx + cx^2$ which is of the same form as Eq. 8. Therefore the form of the parabola of Eq. 8 is determined only by the value of c, while its position is determined by a and b.

If K is the apex of a parabola, J is a point on the curve, and H is the base of a perpendicular dropped from J to the axis, then H is the focus if $JH/KJ = 2$. Therefore we may find H by laying off the angle $HKJ = 63\frac{1}{2}$ degrees, and dropping a perpendicular to the axis from the point where the line KJ cuts the curve. This only holds good when the scales for x and y are equal, as in HKJ, Fig. 6. If in Eq. 9 the scale of x is $1'' = g$ and scale of y is $1'' = h$, the tangent of $HKJ = 2h/g$. In BOA, Fig. 6, the scale of y (velocity) is twice the scale of x (depth) so that $g = 2h$ and the tangent of $BOA = 1$. Since $AB = HJ = p$, we have from Eq. 9, $y = x^2/2(JH)$.

In Merriman's "Method of Least Squares," p. 132, he gives the velocities at different depths below the surface, from Humphreys and Abbot, "Physics and Hydraulics of the Mississippi River," as in Table III. Merriman assumes that Eq. 8 applies, and it may be readily shown that this is justified. The parabolas in Fig. 6 are plotted from the above table and differ only in the scale of velocity. It will be seen that the

TABLE III.

Velocity in Feet per Second.	Depth.	x	y
3.1950	0	+ .3	.0661
3.2299	.1	+ .2	.0312
3.2532	.2	+ .1	.0079
3.2611	.3	0	0
3.2516	.4	− .1	.0100
3.2282	.5	− .2	.0329
3.1807	.6	− .3	.0804
3.1266	.7	− .4	.1345
3.0594	.8	− .5	.2017
2.9759	.9	− .6	.2852

apex of the parabola lies approximately at .3 the depth. Taking this point as the origin, we have for values of x, distances above or below the axis of the parabola (in tenths of depth of the river) and for y, the maximum velocity, 3.2611, minus the actual velocity at the point under consideration. Values of x and y, thus obtained, have been already given in Table III.

The line EF in Fig. 6 was obtained by plotting the logarithm of y against the logarithm of x. At values of x of .2 and .3 we have two points, one from the portion of the curve above the axis, and the other from the part below. The tangent of the slope of line EF is equal to 2, which, as we shall see later, indicates that Eq. 8 applies to this case. In Fig. 6, $HJ = p = .63$, so that the equation of the curve is $x^2 = 1.26y$ or $y = 0.793x^2$. If we move the origin to the surface of the water, where the depth and velocity are both equal to zero, we have $Y = 3.26 - y =$ velocity; $X = x - .3 =$ depth, and our equation becomes, $0.793(x - .3)^2 = 3.26 - y$, or $y = 3.19 + 0.475x - 0.793x^2$.

In a paper presented before the Engineers' Club of St. Louis* Prof. A. S. Langsdorf suggests a method of bringing the general equation of a parabola, with vertex at (b, a), into the form of a straight line equation, so that the constants may be more readily determined. This equation is $y - a = k(x - b)^n$ (Eq. 10) and upon differentiating it we obtain

* *Journal of the Association of Engineering Societies*, June, 1904.

$dy/dx = kn(x-b)^{n-1}$ (Eq. 11) which is similar to the equation for a parabola with vertex at the origin, namely, $y = kx^n$ (Eq. 12) and may be solved by the same method. Therefore, before applying Eq. 11 to our Mississippi River problem, let us consider Eq. 12 and its application to another problem.

Any equation of the form of Eq. 12, which is a parabola if n is positive, and a hyperbola if n is negative, will plot as a

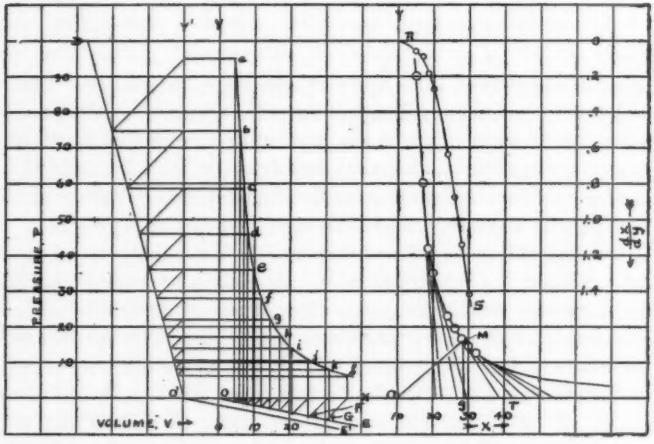

FIG. 8. FIG. 9.

straight line on logarithmic paper. We are then able to treat any curve, so plotted, as a straight line, and can exterpolate without spending the time to find the equation of the curve, or apply the method of least squares just as it was applied in Problem 1. While exterpolation of this kind is accurate enough mathematically, it should be observed that it is a dangerous practice unless it is certain that the same physical law holds good in the new, as in the experimentally determined portion of the curve. Formulas of the form of Eq. 12, which are met with in the every day practice of an

engineer, are,

Area $= \frac{\pi d^2}{4}$.

Deflection of a free beam, due to concentrated load $P, = \frac{Pl^3}{48EI}$.

Moment of inertia of a circular section $= \frac{\pi d^4}{64}$.

Time of oscillation of a pendulum, $= \frac{\pi}{\sqrt{g}} \sqrt{l}$.

In the *Electrical World* of May 3, 1913, Mr. L. A. Doggett uses logarithmic paper to obtain a straight line when plotting the weight of a prime mover against the ratio K.W./r.p.m.

If the exponent, n, is equal to 2, we have a conic parabola, as in Eq. 9, and we may use the method already given for finding the parameter, but this method does not apply if n has any other value.

The rotation losses in a steam turbine may be expressed by Eq. 12, where $y =$ losses in K.W., and $x =$ r.p.m. or peripheral velocity. The points indicated in Table IV, read from diagram on page 120 of Moyer's "Steam Turbines," represent disk and blade rotation losses of a 250 K.W. turbine generator.

TABLE IV.

r.p.m.	K.W.	Values of k if $n = 2.87$.
2,220	5	$.124 \times 10^{-6}$
2,810	10	.127
3,270	15	.123
3,580	20	.126
3,850	25	.128
4,130	30	.126

Eq. 12 may be written, $\log y = \log k + \log x$ (Eq. 13) which is of linear form, which is the reason the curve is straight when plotted on logarithmic paper. Line AB on Fig. 7 shows the points plotted and a straight line drawn to average them. The tangent of the angle between the line and the X axis gives the value of $n = 2.87$, and the intercept on the Y axis gives the value of k. In Problem 1, the intercept was found on the

ordinate through the origin, where $x=0$, but there is no zero on logarithmic paper which we are using in Fig. 7. If $x=1$, $x^n=1$, and therefore, in Eq. 12, $y=k$ if $x=1$. Hence we must find the intercept of the line AB on the ordinate where $x=1$ and log $x=0$. In the present case this ordinate lies off the paper, but the intercept may be found as follows. The base of our logarithmic paper is 10 cm. so that this is the distance between the ordinates $x=1$ and $x=10$. The line AB runs off the paper at the point where $y=1$ K.W. and at a distance of 1.02 cm. from the ordinate, $x=1{,}000$, or 30.02 cm.

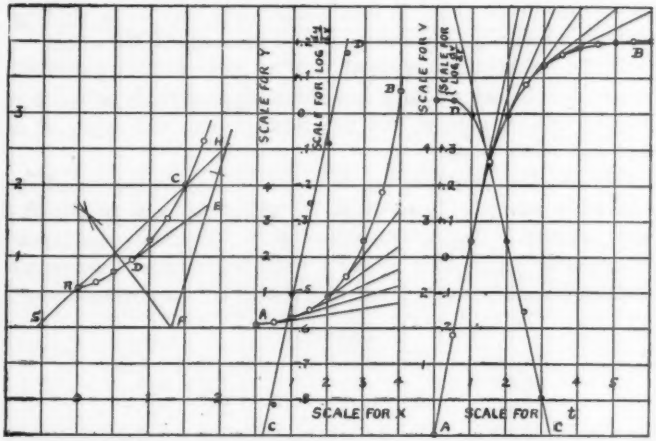

FIG. 10 FIG. 11 FIG. 12

from $x=1$. The slope of the line is 2.87 so that in running 30.02 cm. horizontally, it must run 86.16 vertically. Every drop of 10 cm. moves the decimal point one place to the left, so that a drop of 80 cm. will bring us to $y=.000{,}000{,}01$ K.W. A further drop of 6.16 cm. gives, as a final result, $y=.000{,}000{,}002{,}42=k$ The equation of the parabola is therefore $y=.000{,}000{,}002{,}42x^{2.87}$. From Eq. 12, $y/x^n=k$, so that we may check the value of k algebraically by taking the value of $n=2.87$ which was found graphically. Values of k, found

in this manner, are given in Table IV, the average value being .000,000,001,26. Palmer, in "Theory of Measurements," p. 200, gives formulæ for finding the intercept if the line runs off the paper.

The most accurate method of finding the equation is by the method of least squares which we have already used in Problem 1. We have six points and only two unknowns in our equation, so that no constants can be found that will exactly satisfy all points, and it is a question of finding the most probable fit to the points. From the six points we get the following six observation or condition equations, of the form of Eq. 13, $\log k$ and n being the unknown constants to be determined.

$$0.6989700 = 3.3463530\,n + \log k,$$
$$1.0000000 = 3.4487063\,n + \log k,$$
$$1.1760913 = 3.5145478\,n + \log k,$$
$$1.3010300 = 3.5538830\,n + \log k,$$
$$1.3979400 = 3.5854607\,n + \log k,$$
$$1.4771213 = 3.6159501\,n + \log k.$$

We are using a more general rule than given under Problem 1, in order to extend it later to cover the case of more than two unknown quantities. Multiply each observation equation by the coefficient of n in that equation and add the six products. Also multiply each equation by the coefficient of $\log k$ in that equation and add; or, when, as here, the coefficient of $\log k$ is unity in all equations, we simply add them as they stand. The two sums thus obtained are the two normal equations, that is, the two simultaneous equations needed for finding the two unknowns. There must always be as many normal equations as there are constants in the equation of the curve. Expressed algebraically, using the notation of Problem 1, the two normal equations are

$$\Sigma y = a\Sigma x + nb$$
$$\Sigma xy = a\Sigma x^2 + b\Sigma x$$

and it was from the general solution of these equations that

Eq. 2 and 3 were obtained. For the case at hand our two normal equations are

$$7.0511526 = 21.0649009\, n + 6 \log k,$$
$$24.8982977 = 74.004396\, n + 21.0649009 \log k,$$

and from their solution, $n = 2.8951346$ and $\log k = \bar{9}.0110264$ or $k = .000,000,001,025,7$.

Let us now return to the application of Eq. 11 to our Mississippi River problem. Let the values of the slope, dy/dx, at different points of the curve, determined graphically, be the abscissæ, and x, the abscissæ of the points of tangency, be the ordinates of a new curve. The abscissa of the point where the new curve intersects the X axis will give the value of b, from which we get values of $x - b$. But from Eq. 11, $\log dy/dx = \log (kn) + (n-1) \log (x-b)$ (Eq. 14) which is similar to Eq. 13, and is linear between $\log dy/dx$ and $\log (x-b)$. If values of $\log (x-b)$ are plotted as abscissæ, and those of $\log dy/dx$ as ordinates, the resulting curve cuts the Y axis where $y = \log (kn)$, and the slope of the line gives the value of $n-1$. The determination of the constants k, n and a is then a simple matter, as shown in the following problem.

We wish to find the equation of the curve KJ, shown on Fig. 6. We have already found, by means of the line EF, that approximately, $n = 2$, and therefore, as an aid in drawing the tangents, we may use the property of a conic parabola, that if G is the intersection of the tangent and the axis, K the vertex, and M the foot of a perpendicular dropped from the point of tangency, L, to the axis, then LG will be the tangent if $KG = KM$. To use this method the position of the axis must be assumed, and here, as before, it was taken at .3 the depth. Table V gives values of dy/dx obtained graphically at each tenth of the depth. The graph of these points, prolonged, line CD on Fig. 6, indicates that $dy/dx = 0$ at .295 depth, which should therefore be the location of the axis of the parabola, but this is so close to the assumed location that a redrawing of the

TABLE V.

Depth.	dy/dx	$x-b$	a
0	.483	+.295	3.1226
.1	.333	+.195	3.1972
.2	.163	+.095	3.2456
.3	0	—.005	3.2611
.4	.163	—.105	3.2423
.5	.333	—.205	3.1932
.6	.503	—.305	3.1037
.7	.662	—.405	2.9917
.8	.810	—.505	2.8505
.9	.966	—.605	2.6772

tangents is not required. Since $x=b$ when $dy/dx=0$, the value of b is .295. $x-b$ in the above table gives the distances of the tangent points from the new axis, and we plot $x-b$ against dy/dx as shown in line CD of Fig. 7. The slope of the line is $.98=n-1$, so that $n=1.98$, to check the value of 2 as found by line EF, Fig. 6. While there is no theoretical reason why a different result should be obtained with the logarithmic paper of Fig. 7, than with the ordinary cross-section paper of Fig. 6, it is evident that $(1.00-.98)/1.00$ is greater than $(2.00-1.98)/2.00$ and is therefore more readily detected graphically. If we prolong line CD of Fig. 7 to the point where $x-b=1$, we may read the value of kn, since then $\log(x-b)=0$, and Eq. 14 becomes $\log dy/dx=\log kn$. Reading $kn=1.6$, since $n=1.98$, we have $k=.808$. We are now in position to find a, since for each of the depths in the above table we have the equation $(\text{velocity}-a)=.808\ (x-.295)^{1.98}$ from which the values of a were computed, the average being 3.0885, so that our equation becomes

$$y-3.0885=.808\ (x-.295)^{1.98}.$$

If we assume, with Merriman, that Eq. 8 applies to this problem, we have nine observation equations, the first three being

$$3.1950=a+0.0b+0.00c,$$
$$3.2299=a+0.1b+0.01c,$$
$$3.2532=a+0.2b+0.04c.$$

The left-hand side of each equation is the velocity at a certain depth, this depth, in tenths of the whole, being the coefficient of b and its square being the coefficient of c. As we have three unknown quantities, a, b and c, we must get three normal equations, the first by multiplying each of the nine observation equations by the coefficient of a and finding the sum of the results; the second by multiplying each of the nine by the coefficient of b in that equation and adding the resulting equations; and the third by multiplying each of the nine by the coefficient of c and adding as before. Adding the equations as they stand, since the coefficient of a is 1, we have

$$31.7616 = 10a + 4.5b + 2.85c,$$

while the second and third normal equations are respectively

$$14.08957 = 4.5a + 2.85b + 2.025c$$

and

$$8.828813 = 2.85a + 2.025b + 1.5333c.$$

From the solution of the three simultaneous equations, we have, $a = 3.19516$, $b = 0.44228$ and $c = -.76502$. In order to reduce Eq. 8 to the simpler form, $y = cx^2$, we must move the origin to a point having the coördinates $x = -b/2c$ and $y = (4ac - b^2)/4c$. In this way we determine that the new origin, or vertex of the parabola, is at a point .289 of the depth below the surface of the water, where the velocity is 3.259 ft. per second.

The Hyperbola.

We have already considered, under straight lines, the simple equilateral hyperbola, the equation for which is $xy = \text{constant}$. If $xy = pv = \text{constant}$, we have the equation of isothermal expansion. But we also have very frequently in thermodynamics the equation $pv^n = \text{constant}$ (Eq. 15) from which we have $\log p + n \log v = \log \text{constant}$ (Eq. 16) which shows that Eq. 15 will plot as a straight line on logarithmic paper. As an illustration we may take the results of a gas engine test, from Gibson, page 125, as in Table VI*a*.

TABLE VI *a*.

v	4.13	4.73	5.35	5.94	6.55	7.14	7.73	8.04
p	115	95	81.4	71.2	63.5	54.6	50.7	45.

v is the volume between the cylinder head and piston, including clearance, and p is the absolute pressure in the cylinder at different points of the stroke. In Fig. 7, line EF, we have plotted p against v on logarithmic paper, and obtain a straight line sloping downward toward the right, instead of downward toward the left, as in the case of a parabola. This line, extended upward, cuts the line, $v=1$, at $p=750$, and the tangent of the angle which EF makes with the horizontal is 1.32, so that the equation of the curve is $pv^{1.32}=750$ as obtained by Gibson.

If the clearance is not known, as may be the case when we are considering the expansion curve on an indicator diagram, we may obtain the clearance by assuming the exponent and using Brauer's method.* To show this method more plainly, we may prolong our curve by exterpolation as in line GH, Fig 7, which is an extension of line EF downward, thus obtaining Table VI*b*.

TABLE VI*b*.

v	10	12	14	16	18	20	25	30	40	50	60
p	35	28	22.7	19	16.4	14.2	10.6	8.2	5.6	4.2	3.3

The position of OY being unknown, we assume $O'Y'$ in Fig. 8. Then $1+\tan DO'Y'=(1+\tan E'O'X)^n$, and taking the exponent, n, equal to 1.32 and letting $\tan E'O'X=.2$, we have, $1+\tan DO'Y'=1.2721$ or $\tan DO'Y'=.272$. The position of the line $O'X$ is known from the atmospheric line on the indicator card. From any point, a, on the expansion curve, draw a horizontal till it intersects the assumed vertical $O'Y'$, then a 45-degree line from this point of intersection to the line $O'D$ and another horizontal through this second point of intersection, reaching the curve at b. The operation is then repeated starting with b, proceeding thus to find a series of points on the curve. It will be noted that the location of

* *Zeitschrift des Vereines deutscher Ingenieure*, 1885, p. 433.

these points is exactly the same as if the line OY had been used instead of the line $O'Y'$, because the point O' is correctly located on the line of zero pressure. We now drop perpendiculars from a, b, etc., and extend them beyond $O'X$. From the intersection of the perpendicular from l with $O'X$ we draw a 45 degree line to intersect the perpendicular from k at G, and from the intersection of kG and $O'X$ we draw a 45-degree line intersecting the perpendicular from j at F. Then O is found at the intersection of $O'X$ with a line drawn through F, G, etc., parallel to $O'E'$, the tangent of the angle GOX being thus made equal to 0.2. The vertical through O gives the line of zero volume from which the clearance may be calculated, since the cylinder volume is given by the atmospheric line on the indicator card.

If the clearance is known, Brauer's method may be used to find the exponent n in Eq. 12. This method was applied to actual indicator cards by Bruno Leinweber and described by him in *Zeitschrift des Vereines deutscher Ingenieure*, April 5, 1913. It shows that n was far from constant. Another method for finding n is given by Ennis in "Applied Thermodynamics," p. 55. Draw the tangent MT and the radius vector MO as in Fig. 9. Drop a perpendicular from M on OT thus locating the point g. Then $n = Og/gT$. The method is, however, very approximate, since the value of n depends entirely upon the location of one tangent, and upon the shape of the curve for only a small portion of its length. Assistance in drawing the tangent may be obtained from the principle that the portion of a tangent intercepted between the asymptotes is bisected by the point of tangency, which follows from the rule that if, as in Fig 10, a straight line cuts a hyperbola at two points R and C, and the asymptotes at H and S, then $HC = RS$. This holds good for any hyperbola, whether or not equilateral.

In applying Langdorf's method to hyperbolas, the general equation may be written in the form $(y - a)(x - b)^n = k$ (Eq. 17) from which we have by differentiating $-dy/dx$

$= kn\,(x-b)^{-(n-1)}$ (Eq. 18). In Fig. 9, x is the abscissa of a point of tangency, and values of x are plotted against dx/dy giving the curve RS. RS prolonged until $dx/dy = 0$, gives $x = b = 10$, thus locating the true asymptote OY, 10 units from the axis of Y assumed in plotting the line RS. There is some difficulty in prolonging RS correctly, but if b is correct, the next curve to be described will be a straight line, whereas it will be curved if b is incorrect or if the assumed data do not give a hyperbola. Having found b, we obtain the values of $x - b$, which are given in the following table, together with data used in finding the line RS.

x	dx/dy	$x-b$	dy/dx
15.0	.06	5.0	16.7
17.0	.09	7.0	11.1
18.5	.19	8.5	5.26
20.0	.27	10.0	3.70
24.0	.64	14.0	1.56
26.0	.88	16.0	1.14
28.0	1.14	18.0	.88
30.0	1.42	20.0	.70
32.0	1.76	22.0	.57

From Eq. 18 we have, $\log(-dy/dx) = \log kn - (n+1)\log(x-b)$ which is the equation of a straight line, from which we may find kn and $n+1$. Plotting dy/dx against $x-b$ as in line IJ, Fig. 7, we find that when $x-b=1$, $dy/dx = kn = 850$, and from the slope of the line, $n+1 = 2.37$ and $n = 1.37$, so that $k = 620$. If the horizontal asymptote is known, that is a is known or equal to zero, we now have the complete equation. Here $y(x-10)^{1.37} = 620$, and if a were unknown we should have $(y-a)(x-10)^{1.37} = 620$, in which a is the only unknown quantity and may be found for any corresponding values of x and y.

It will be noted that the values of n and k were found without locating the horizontal asymptote, as would be necessary if Langdorf's method were not used. Though not as simple, and hence less accurate than the logarithmic paper

method when a and b are zero or known values, it is the preferable method when one or both of them are unknown.

A rating curve for current meters is an example of a hyperbola of the form $v = a + bn + c/v$, which is considered by Rateau in *Annales des Mines*, 1898, page 370. v is the velocity of current, and n is the number of revolutions of the meter in a unit of time. This form of equation may be derived from the more usual form $x^2/A^2 - y^2/B^2 = 1$ (Eq. 19) by turning the axes so that one asymptote coincides with the axis of X, and then moving the Y axis through a distance a.* Since the rating curve for a current meter is practically a straight line, except for very low velocities, we may, for the sake of clearness, take a more pronounced curve, in accordance with the data of Table VII.

TABLE VII.

x.	y.	c.
0	0.56	2.85
.25	0.63	2.71
.50	0.77	2.75
.75	0.96	2.77
1.00	1.22	2.79
1.25	1.53	2.80
1.50	2.00	2.70
1.75	2.60	2.77

In Fig. 10 we have the axis of X as one asymptote, and may find the other by making $HC = RS$ as previously explained. The assumed origin is at a distance along the X axis of $-1.31 = a/b$, from the point of intersection of the second asymptote, FH, with the X axis, and the tangent of the slope of $FH = b = 3.46$, so that $a = -4.53$. Thus we have the equation, $y = -4.53 + 3.46x + c/y$ from which to find c by introducing corresponding values of x and y. In this way we have the values of c as given in Table VII, with an average value of $c = 2.77$, so that the complete equation of our curve is

$$y = 3.46x - 4.53 + 2.77/y.$$

* The method of changing the origin and direction of axes may be found, for example, on page 53 of "Mathematics for Engineering Students," by Keller and Knox.

We may check this result by obtaining the equation graphically in the form of Eq. 19, and changing the axes. The new axis of X is found by bisecting the angle SFH and then $DF = A = 1.10$, and $DE = B = 1.46$, B being measured perpendicularly to A. Now to get back to our original axes we must revolve the axes through the angle whose tangent is B/A. Using the transformation formulæ

$$y' = x \sin\theta + y \cos\theta,$$
$$x' = x \cos\theta - y \sin\theta,$$

where $\tan\theta = B/A$, we find that

$$2x(AB^3 + A^3B) + y(A^4 - B^4) = -A^2B^2(A^2 + B^2)$$

or

$$y = \frac{2(AB^3 + A^3B)}{(B^4 - A^4)}\, x + \frac{A^2B^2(A^2 + B^2)}{y(B^4 - A^4)},$$

so that we may get b and c in the equation $y = a + bx + c/y$ from

$$b = \frac{2(AB^3 + A^3B)}{(B^4 - A^4)}$$

and

$$c = \frac{A^2B^2(A^2 + B^2)}{(B^4 - A^4)}.$$

Substituting $A = 1.46$ and $B = 1.10$, we have $b = 3.48$ and $c = 2.79$ so that finally,

$$y = 3.48(x - 1.31) + 2.79/y$$

or

$$y = 3.48x - 4.56 + 2.79/y,$$

which is a fairly close check on the equation previously obtained.

Logarithmic Curve.

The equation of a logarithmic curve, asymptotic to the X axis, is $y = ae^{bx}$ or more generally, $y - y' = ae^{bx}$ (Eq. 20) from which Langsdorf obtains $dy/dx = abe^{bx}$. Log $dy/dx = \log ab + bx \log e = \log ab + .4342bx$, which shows a straight

line relation between dy/dx and x, with slope equal to $.4342b$ and intercept on the Y axis equal to $\log ab$.

We may take for our curve the values of x and y of Table VIII, from which the values of dy/dx are obtained graphically.

TABLE VIII.

x.	y.	dy/dx.
0	.09	...
0.5	.15	.154
1.0	.26	.311
1.5	.49	.560
2.0	.83	.815
2.5	1.42	1.482

Fig. 11 shows $\log dy/dx$ plotted against x. Averaging the points by a straight line, the tangent of the slope is $.480 = .4342b$, while the intercept on the Y axis, where $x=1$, is $-1.00 = \log ab$. From this, $b = 1.105$, and as the antilog of 1.0000 is $.10 = ab$, we find $a = .0905$.

In the *Wisconsin Engineer* for December, 1908, L. F. Harza gives the curve between $x = t =$ time in seconds, and $y = v =$ velocity of water in a closed pipe accelerating from rest The equation of the curve is

$$v = \frac{Ve^{kt} - 1}{e^{kt} + 1} \text{ (Eq. 21)},$$

where V is the maximum value of v. This equation may be transformed into $1/(V-v)-(1/2V)=(1/2V)e^{kt}$ which is in the same form as Eq. 20. In fact data for our logarithmic curve were obtained by sealing values of V, v and t from Harza's curve, and then taking values of $1/(V-v)-(1/2V)$ as ordinates and t as abscissæ. V was scaled as 5.56 and therefore $1/2V = .09$ should be the value of a in Eq. 20, as was obtained graphically. Furthermore, $(y-y')/a = (V+v)/(V-v) = e^{kt}$, from which k may be obtained since it is the only unknown quantity, giving values shown in Table IX. It will be seen that the value of 1.105, determined graphically, agrees very well with the average of the more consistent values of k.

TABLE IX.

v	t	e^{kt}	k
0	0	1.00	—
1.40	0.5	1.67	1.028
2.72	1.0	2.92	1.070
3.84	1.5	5.46	1.128
4.48	2.0	9.30	1.114
4.90	2.5	15.8	1.103
5.17	3.0	27.6	1.105
5.33	3.5	47.3	1.100
5.43	4.0	84.3	1.108
5.49	4.5	158.	1.126
5.51	5.0	221.	1.078
5.52	5.5	276.	1.020
5.53	6.0	369.	—

Harza's curve may be used directly to find values of the constants graphically. If we differentiate Eq. 21 we obtain

$$dv/dt = \frac{2Vke^{kt}}{(e^{kt}+1)^2} \text{(Eq. 22)}.$$

We may find dv/dt graphically, or we may calculate values by taking $k=1.105$, $V=5.56$ and $e=2.72$. Table X shows results found by calculation, and graphically in Fig. 12.

TABLE X.

t.	dv/dt Calculated.	dv/dt Found Graphically.
0	3.06	2.73
0.5	2.84	2.73
1.0	2.28	2.50
1.5	1.65	1.82
2.0	1.095	1.10
2.5	.688	.70
3.0	.414	.40
3.5	.245	.25
4.0	.144	...

In Fig. 12, where the graphically found values of dv/dt are plotted against t, it is seen that for high values of t the line is straight, but it becomes curved at the end since in the denominator of the second term of Eq. 22, the 1 becomes of importance in comparison with e^{kt}. If we neglect the 1,

and take the logarithm of both sides of Eq. 22, we have log $dv/dt = \log 2Vk - kt \log e = .4342kt$. This shows that dv/dt plotted against t would give a straight line, except for the influence of the 1, and that the intercept on the Y axis of the straight part of the curve, extended, will give log $2Vk$, while the tangent of the slope will be equal to $.4342k$. Applying this graphical method in Fig. 12, we find log $2Vk = .90$ or $2Vk = 7.95$, and since the tangent of the slope is .42, we have $k = .966$, from which $V = 4.12$.

When $t = 0$ Eq. 22 becomes $dv/dt = 2Vk/4 = Vk/2$. Since we found graphically that $dv/dt = 2.73$ at this point, we have $Vk = 5.46$ to check 1.105 multiplied by $5.56 = 6.15 = Vk$.

Conclusion.

A very important problem in connection with the determination of the equations of curves, is to find the degree of accuracy with which the equation fits the assumed points. We have omitted this entirely, because it is a distinctly separate subject though closely related. The simpler measures of precision are considered in Goodwin's "Precision of Measurements and Graphical Methods," while the more complex methods, as Professor Goodwin remarks, are only used in books on the method of least squares. To these same books on least squares the reader must be referred for methods of determining the equation of a curve involving more extended use of the calculus, but with the warning that a lengthy calculation sometimes leads to nothing but an opportunity to make another guess. Sooner or later we must reach a point where mathematics fail us, and we can only apply the saying, "Was man nicht ausrechnen kann, nimmt man ganz beliebig an."

THE ENGINEERING STUDENT IN EUROPE AND AMERICA.*

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Although my connection with university life in this country covers a period of little more than two years, I believe that the very fact of my still being, as it were, in the shallower portions of the pedagogical rut may actually enhance, rather than detract from, the value of such observations and comments as my experience on both sides of the Atlantic may seem to warrant.

It is generally conceded that the object of an education at an engineering university is not so much to turn out specialists in a particular line of work, as to train the student in accurate methods of thought, and equip him physically, mentally, and morally, to deal wisely with the difficulties that are likely to beset him after the close of his college career. A graduate of any one of the great engineering universities should at least be able to feel that his time has not been wasted; that, so far as it is possible to train and equip a man for the highest positions in the engineering world, he has been so trained and equipped; and that, given the requisite personal qualities and a suitable environment, he can attain to these high and—incidentally—lucrative positions.

This is the man I have in mind: a young man leaving the university to follow the line of work for which he has been trained, and seeking as an ultimate goal—whether for mercenary or for nobler reasons—a position at the head of his chosen profession. This eliminates from our present point of view, the man who aspires to be no more than a skillful artisan; and although there are many whose circumstances and

* This article is based upon an informal address delivered to students of Purdue University in February, 1915.

financial means render difficult, if not impossible, the attainment of the higher positions, these are rarely the men who have had the advantages of a university education.

The subject of this article might perhaps be treated under two main headings: (1) the differences in education and training of the European and the American engineer, and (2) the differences in results obtained on the two continents.

It will not be necessary to discuss in detail the methods of American universities; these vary somewhat in the different localities, but in case my remarks should not be of general application, it may be wise to state that my own experience has been of the Middle West only. I shall do little more than call attention to certain broad distinctions that seem to exist between the European and the American trained engineer; and such conclusions as I have drawn from my observations, however just they may appear to me at the present time, are not put forward in any didactic spirit, seeing that they may conceivably be modified by a longer residence in this country.

Although my European experience is confined mainly to Great Britain, I am aware of the fact that, for purely scientific training apart from its practical application, the technical high schools of Germany, as for example those of Charlottenburg, Dresden, or Hanover, rank among the best in Europe. In the matter of chemistry and chemical engineering, the superiority of the German training is generally recognized. For the civil engineer, France offers excellent training.

In England, the universities of Birmingham, Cambridge, London (King's College), Liverpool, Manchester, and several others, not to mention the many technical colleges and training institutes, provide courses for engineering students, usually extending over three years. The training of a young mechanical or electrical engineer in England is rarely considered complete unless he has spent at least two years as an apprentice in the workshops of some engineering firm of recognized standing.

The standard of general education required of university

students in England is probably higher than the average standard in America: the university graduate, whatever the line of study he may have followed, is usually a well educated man, of broad outlook, whose mind has been so trained that he should be able, if necessary, to specialize along more than one line: it is rarely possible for a young man, before the termination of his college career, to foresee the nature of the work in which his inherited endowment and acquired intellectual capability will render his ultimate success most probable.

In Germany, the general education is carried further than in America, and also further than in many of the colleges in England. The German student will be twenty-four years of age or more before he can complete the usual course of training in engineering. This does not include the one year of military service required before he can take up a regular appointment.

The chief advantages of America for the training of engineers are the well equipped laboratories and workshops attached to many of the universities and training institutions, and the facilities afforded to students for getting practical experience in works. In Europe, the graduate student, however successful in his college career, frequently experiences difficulty in obtaining remunerative employment. In America, the conditions, until recently, have been distinctly more favorable in this respect: a graduate student can usually obtain employment at a living wage, with which he should, indeed, be entirely satisfied during the first twelve months or two years: the young man without previous experience of engineering work, who considers such payment inadequate, is usually laboring under a misconception regarding the real value of his services to the employer.

One point of great interest in comparing the methods followed in Europe and America is the fact that final examinations count for much more in the Old World—particularly in Germany—than they do here. Notwithstanding the many objections to the system of giving searching and comprehensive

examinations before passing out a man as a graduate of a technical university, it is considered by the majority of European teachers to produce a higher standard of trained men by eliminating the unfit. As a general statement it may be said that the parental policy of pushing or coaxing a student through school is not followed in the European universities. It is assumed that the student who presents himself for a course in engineering does so of his own free will, knowing well that he is required to attain a certain standard of knowledge and proficiency, and that his failure to reach that standard will inevitably stand in the way of his graduation.

I am not blind to the fact that the early training, environment, and immediate prospect, of young men following a university course differ appreciably in Europe and America, and that certain differences in treatment may, therefore, be desirable if not necessary; but the thing I am trying to express seems worth stating. I do not know if American universities follow any consistent policy in the matter of discouraging and eliminating those students who, through inaptitude or inadequate early training, cannot attain the requisite standard of knowledge and be a credit to the university after graduation; but I can imagine with extraordinary facility the temptation to lower this standard in order to attain certain financial or political ends. I believe that, just as a higher standard of general education is insisted upon when entering the university course, so the standard of attainment at the end of this course is somewhat higher in Europe than in America. It is by the final examinations covering a considerable amount of ground broadly yet thoroughly that the high standard is maintained, regardless of political or other worthless if not ignoble motives which might tend to lower it. It may be urged that a state-supported institution owes a debt to the people of the state which may adequately be discharged by raising to a level of intellectual mediocrity the largest possible number of the younger generation; but whether or not this function of a university would be in the true interest of the state is at

least disputable; and any university, considered as a seat of learning, which, instead of helping the highest type of mind to the attainment of its high ideals, would, through any fault in administration or for any reason whatsoever, act as a drag on the aspirations of the talented few, should surely rank among the many dismal failures of human endeavor. On the other hand, if it is possible to reconcile the two seemingly conflicting functions of teaching institutions—to put, as it were, the grain and the chaff through the one mill—giving to the larger number what they need, without denying the select minority what it craves for, then a useful and worthy end has been attained. I cannot depart from my original assertion that a university course should fit a man who is otherwise suitably endowed, to reach—after years of diligent endeavor—the high positions in his chosen profession.

Apart from the question of technical training, the European student has exceptional opportunities for general culture; he has an undoubted advantage in the matter of architecture, picture galleries, museums, music, and all such influences as tend, by the development of the emotional nature along with his intellectual growth, to the rounding off or softening of rugged outlines. These differences of environment and opportunity must not be lost sight of in what follows, wherein I shall attempt to state some personal impressions relating to the finished product of the universities, namely, the young college-trained engineer in Europe and in America.

The chief difference I have observed is in the matter of imagination, of originality, of the speculative mind which seeks an answer to questions of a purely intellectual interest. entirely apart from their commercial or so-called "utilitarian" value. Such questions should present themselves for serious and urgent consideration to every active and healthy mind; but particularly to the mind of the incipient engineer. A large number of undergraduates in the engineering universities are deficient in this respect, that is to say, they are not tuned up to the pitch where abstract questions of a purely

speculative character become of enthralling interest; and I believe that the percentage of university students whose lives, because of this deficiency, are bound to be incomplete, however apparently successful, is greater in America than in Europe. If a young man does not find a fascination in the pursuit of knowledge for its own sake; if he does not follow the elusive truth persistently, unflinchingly, until he has tracked it down, then, it seems to me, he must be sadly lacking in the creative faculty, which requires not only imagination, but also the stimulus which urges the diligent scientist toward the ultimate solution of the problem he has set himself. And what sort of an engineer is a man without the creative faculty? He cannot be a great engineer although he may be a clever artisan. America is proud, and justly proud, of her great inventors and engineers, yet I venture the statement that, among the average man, many of whom do great things without enjoying the doubtful advantage of newspaper notoriety, those from the European schools have more originality, a keener imagination, and greater potentialities as creators of new combinations of things than the average college-trained man in this country.

The American engineer has the practical end always in view, and that is why, in the adaptation of new ideas—which may or may not have originated in Europe—he is supreme. He is unsurpassed in the matter of adapting the more or less visionary creations of the inventor to useful ends.

In order to emphasize this difference that I believe to exist between young men educated in the Old and in the New World, I might say that the engineering student in England or on the continent of Europe has a greater respect for abstract ideas than the average young American; his imagination will permit him to contemplate and apprehend those realities which are with difficulty expressed in material form yet which, to the poet or artist or speculative thinker, are not less substantial than the greatest material achievements of the practical man. It may be argued that, since the engineer

deals in material things, and since the cost of his works or structures is a matter of the utmost importance, he need neither look beyond his nose nor take interest in things of which the monetary value is not immediately obvious. That this argument is shallow, most educated persons will admit. If it is true—as believed, if not conceded, by many—that the first consideration in life is to amass material wealth, and that the formation of character is of secondary importance, yet, even so, the engineer who has no bent for abstract speculation and who neglects to cultivate the imagination, will not as a rule, unless his methods are dishonest, be to any marked degree "successful," *i. e.*, encumbered with a plethora of material possessions.

In case it should be thought that I would discountenance efforts made toward a purely practical or utilitarian end, I hasten to state my very firm conviction that the basis of all true engineering is to be found in economic science: the engineer is not merely interested in questions involving dollars and cents; he is vitally concerned with costs and profits, being in fact rarely influenced by any other consideration. The engineer must therefore be practical, with an intimate knowledge of the uses and values of material things; he must build strongly and lastingly, yet with true economy of material and labor; but I maintain that none of these requirements stand in the way of his being well grounded in fundamental theory; of a speculative and original turn of mind; imaginative in the sense of his being able to combine old ideas in the creation of new utilities, and relentless in his opposition to the tyranny of convention, which insists upon debasing the individual to the stagnant level of an unreasonng majority.

Admitting, then, the practical and apparently prosaic work of the engineer to be the shaping and adaptation of tangible materials to useful ends, on the most economical basis, why—it may be asked—should he not take the shortest path and make a straight cut for the desired goal, regardless of abstract speculations and intellectual soarings, to say nothing of the

emotional moods to which these usually owe their origin? My reply may be summed up in the commonplace saying that it is the outsider who sees most of the game. If I may be permitted to state what I believe to be a weakness of the young American college-trained engineer, it is precisely this tendency to make a bee line for the end in view, forgetting always that the goal he sees—which is almost invariably the goal as seen by equally shrewd and similariy trained young men—does not necessarily present the same appearance from other points of view. It is only by the broad outlook, by an enlarged experience of many aspects of human activity, that it is possible to see at all clearly even the fractional part which man is ever permitted to see of the thing he contemplates. A wide knowledge of facts, not obviously connected with the problem on hand, must—when wisely coördinated by a trained intellect, kindled by imagination, yet tempered by sound judgment —lead to results of inestimably greater value than those attained by the man of limited outlook, even though he be the most untiring "hustler" of "aggressive" personality, with unlimited faith in the penetrative power of repeated frontal attacks.

The engineering student in all countries, but especially in America, is apt to think that what is not directly connected with engineering is not worthy of his attention, because it will have no influence on the amount of his monthly salary. Apart from the questionable propriety of reducing all values in this life to a monetary basis, this attitude of mind is bad, for two reasons. In the first place, neither the student nor his teachers can say what is and what is not directly connected with engineering, and, in the second place, it is not true that matters apparently unconnected with the science and practice of engineering, are without influence on the monthly salary.

Consider, for instance, the study of language. The engineering student in Europe is readily convinced that the ability to express his thoughts clearly in his own language is essential to his success, and that the value of the "humanities" and

so-called cultural subjects is not to be underrated. The American student, on the other hand, is not always satisfied that a working knowledge of English is necessary to his ultimate success as an engineer. I do not think this is so because he lacks ambition, or intends to remain all his life on the lower rungs of the ladder; but simply because he believes the study of the purely technical subjects connected with engineering to be of primal importance. Considered merely as a help to the clear expression of facts and requirements in reports or specifications, there is surely an obvious monetary value in being able to understand one's own language, and use it effectively; but the intelligent study of language, and a knowledge of several tongues, may mean far more than this. Although I would not assert that a thorough grounding in Latin and Greek is essential to success in engineering, I find it difficult to discriminate between the engineer and the man. What is good for the man is generally good for the engineer. Why should the term "the humanities" have been applied to classical learning if it was not the belief of those best qualified to hold an opinion that these studies contribute most to the development of true humanity? It is by the highest culture of the human faculties that man becomes truly man. The engineer should be more than a tool, more than a clever copyist. If he is not in the first place a man, with the vision, judgment, and self control, which depend largely upon an all-round culture of the mind, he cannot reasonably aspire to be a great engineer. It is through the fundamental study of language, including necessarily some study of poetry—not only of the "fossil poetry" in words, but of the emotional values of rhythmic combinations of words—that a man may ultimately attain ascendency over other men. Not only what he sees and knows, but likewise what he conceives and feels, may, through language, be made clear to others, who may thus be led to apprehend new, and possibly revolutionary, aspects of a generally unappreciated truth.

Max Müller has taken pains to show that, just as language

is the mode of expression peculiar to reasoning beings, so, conversely, there can be no reason without language. Whether or not we "think in words" it must be admitted that great thinkers usually have a command of language which enables them to express their thoughts clearly. They may not always have a large vocabulary, but they know the origin and value of the words they use, and are therefore able to express themselves correctly in language that is intelligible to educated men. I do not mean to imply that every incessant talker or fluent politician is a deep thinker; but I believe that the true orator, and the less brilliant but equally rare conversationalist, must necessarily be thinkers. A knowledge and command of language lead to a respect for words which checks the utterance of much that is foolish and vulgar, thus allowing ample time for the cultivation of the thinking habit, which is less easily acquired than is generally supposed. Thus, it may be said that language is more than a means of expression; it actually nourishes and promotes thought.

Now, every engineering student who aspires to greatness in his profession, must face the fact that he will—sooner or later—be called upon to exercise his reasoning faculties. He must do what very few of his fellows, and not many of his elders, have ever even tried to do; he must learn to think! Very young people, whose brains are naturally active, are led to believe that older people think deeply and are influenced by decisions arrived at through a mental process in which their reasoning faculties play an important part. Later in life, if their own power of reasoning is not atrophied through lack of use, they will become conscious of the fact that their early belief must have been fostered by fools or imposters. Because man is a reasonable being—endowed with reason and capable of reasoning—it does not follow that he habitually exercises, or relies upon, his reason. The average man does not think. The average engineer can earn an average wage and serve his fellows as well as they serve him, without endangering his reason through excessive use. But the great man and the

truly great engineer must be reasoning as well as reasonable beings. Thomas Carlyle was a great thinker and, from his great and lonely height, he could look down upon the fellow men and judge them rightly. It was he who said: "Truly a Thinking man is the worst enemy the Prince of Darkness can have; every time such a one announces himself, I doubt not, there runs a shudder through the Nether Empire; and new Emissaries are trained, with new tactics, to, if possible, entrap him, and hoodwink and handcuff him."* Judging by the achievements of the said emissaries, the thinking man is no less a rarity at the present time than he was in Carlyle's day.

To sum up the situation as I view it, there would seem to be a use for imagination, for accurate thinking, and for individual judgment, in engineering as in every other line of intellectual and artistic work; yet the tendency to push aside as relatively unimportant the non-technical and so-called cultural studies, is characteristic of many engineering universities; being, however, more apparent in America than in Europe.

It was not my original intention to offer advice; but merely to draw attention to noticeable differences, and make a simple record of my impressions. I would, however, like to say that if the American is handicapped to some extent in being denied certain opportunities for general culture which are the monopoly of Europe, he need never deny himself the companionship of books. The American young man is more independent, more intimately in touch with his surroundings, more observant, and more resourceful, at a comparatively early age, than the young European; and when he develops an interest in imaginative literature—of which the value lies in its stimulative and suggestive power rather than in any statement of apparent facts—he rapidly gains that broader and more sympathetic view of men and things without which the greatest ends are rarely achieved. If the average engineering student

* "Sartor Resartus."

will think less of what he has and what he may get, and more of what he is and what he may become, there is a probability that he may accomplish in the future things even greater and more lasting than have been accomplished in the past.

In conclusion, let me express the hope that my thoughts have not been so loosely put together as to suggest that I would advocate a superficial acquaintance with many subjects, rather than a sound knowledge of the fundamentals of scientific engineering. Superficiality—the kind of dilettantism which is content to lick the rind of innumerable and various untasted intellectual fruits—is always to be deprecated. Let us by all means be honest, and admit, when occasion arises, the limits to our knowledge; but let us not rest satisfied until we have cultivated the broad outlook which will enable us to appreciate, and sympathize with, interests and attitudes of mind not identical with our own. It should be possible to appreciate not only the line of reasoning of our fellow man, but also the emotions by which he is stirred and influenced. In the schools we become familiar with analysis; we tear everything to pieces that we may understand how it is constructed; but we have little practice in the process of building up. It is possible that less analysis and more synthesis would be good for all of us; but what we do not learn in the class room, we may acquire elsewhere; and it is by a broadening of the viewpoint and a continual struggling against the constraint and ultimate extinction of the imagination that much may be accomplished. The man who is to conceive and build new machines, or carry out great engineering projects, must have some originality. A man may be original without being an eccentric of the mentally unbalanced or self-advertising class. If a man does not express *himself* in his works, he is doing no more than the little, or the nearly great, man, who is content to repeat what has been done before. Not imagination only, but also those indefinable yet invaluable qualities known as character and personality are closely allied to what is usually referred to as originality; and if originality is to be discour-

aged in favor of ideals of universal application it is not alone the profession of engineering, but the business of life itself, which is liable to become dull and spiritless.

The creative power, duly limited and controlled by experience and sound judgment, is essential to the great engineer; and my argument briefly amounts to this, namely that all broadening influences, all emotional as well as intellectual advances, and all experiences tending to the development of a vivid and fertile imagination, are as necessary to success in engineering as they are to the full appreciation and enjoyment of life.

LAND GRANT COLLEGE ENGINEERING ASSOCIATION.

BY H. W. TYLER, PRESIDENT.

This Association was organized at a meeting of presidents and deans of engineering in the land grant colleges of the country held at Washington in January, 1913, and attended by representatives from twenty-six states.

A second meeting the following November was attended by representatives from thirty-two states, and that in November, 1914, by representatives from the same number.

The objects of the Association as defined in the constitution are the discussion of questions affecting the progress and welfare of the engineering division of the Land Grant Colleges and the general public service rendered by these divisions. The article continues:

"The Association shall work in as close coöperation as practicable with the Association of American Agricultural Colleges and Experiment Stations."

It was fully appreciated that the interests of engineering education in general were admirably represented by the Society for the Promotion of Engineering Education, but it seemed to the persons interested in the organization of the Land Grant College Engineering Association that the engineering departments of these institutions had important and well-defined relations, mainly of an administrative sort, which were not adequately covered either in the Society for the Promotion of Engineering Education or in the Association of Agricultural Colleges and Experiment Stations. This latter body had long exercised an important influence on the development of the institutions composing it and on national legislation affecting them, but it had become for various reasons predominantly interested in the agricultural side of their work, and the deans of the engineering department were seriously

concerned to bring about a better balance of interest on the part of the Association in its two great fields.

The program of the first meeting included besides questions of organization and affiliation with the older body, meeting at the same time and place, important and interesting discussions on engineering extension, engineering experiment station work, the development of industrial education in schools lower than collegiate grade, etc.

The proceedings of the meeting of November, 1913, included extended discussion of the meaning of mechanic arts in the Act of 1862, of relations between the division of agricultural and engineering, of military drill at land grant colleges, of aid to state governments by land grant colleges, and further discussion of engineering experiment stations and engineering extension.

The main features at the meeting on November, 1914, were as follows:

A general discussion of the functions of a university and of coöperative extension work in agricultural and engineering, led by Commissioner Claxton of the Bureau of Education.

Reports on legislation and judicial decisions affecting the status of engineering at land grant colleges in states where engineering is also taught at a state institution.

Organization for engineering extension work, etc., etc.

After negotiation with the executive committee of the Association of Agricultural Colleges and Experiment Stations, it was voted by the latter body that its section on College Work and Administration be requested to organize a division of engineering, and that the officers prepare separate or joint programs—as may be deemed best—in providing for engineering meetings in connection with the next annual meeting of this Association.

Under the terms of this vote the next meetings of both associations have been called at San Francisco, August 11–13.

The present officers of the Engineering Association are:

President, H. W. Tyler, Massachusetts Institute of Technology, Secretary, G. W. Bissell, Michigan Agricultural College.

The Association owes much of the good it has thus far accomplished to the energy and enthusiasm of Hon. J. P. Jackson, late dean of engineering at Pennsylvania State College, and Dean Anson Marston of Iowa.

Copies of the published proceedings of the three meetings thus far held are available to a limited extent on application to the secretary.

ENGINEERING EXPERIMENTATION AND ENGINEERING EXTENSION AT IOWA STATE COLLEGE.

BY CHAS. S. NICHOLS,

Assistant to the Dean, and Director of the Division of Engineering, Iowa State College.

The functions of engineering schools the country over are expanding year after year. At first such schools generally were content to give engineering instruction within their own confines; now many are extending their activities to cover some outside fields.

One very proper addition to college activities is engineering research, not alone for the advancement of purely scientific or technical knowledge, but also to aid in the industrial development of the community, state or nation. Such research has long been in favor, but is now receiving formal recognition and systematic organization.

Mention may be made of the Massachusetts Institute of Technology and of the University of Pittsburgh as institutions performing research work of value in the development of the industries. The Mellon School of Specific Industries at the latter institution is unique in its operation. With the active coöperation and support of the industries themselves, this department of the university is devoted exclusively to the work of developing many new and valuable processes which will be of immense value to the country as a whole.

The Engineering Experiment Station, however, is rapidly becoming the favorite organization for engineering research.

Another innovation of comparatively recent origin is engineering extension work, in the trade education of mechanics and in the general spread of technical information among the public and especially public officials. The University of Wisconsin has performed pioneer work along this important

line, and its influence is being increasingly felt. Iowa State College has actively adopted the plan with modifications to suit Iowa conditions, and engineering schools the country over are giving much consideration to the subject.

State institutions are especially obligated to participate actively in industrial development and in extension work.

State institutions operating under the Land Grant Acts are even further obligated by the legal requirements of the Morrill Laws, which specifically provide for "the liberal and practical education of the industrial classes in the several pursuits and professions of life," and for reporting on "experiments made . . . with their results, and such other matters, including State industrial and economic statistics, as may be supposed useful"; in such manner as the legislatures of the states may prescribe.

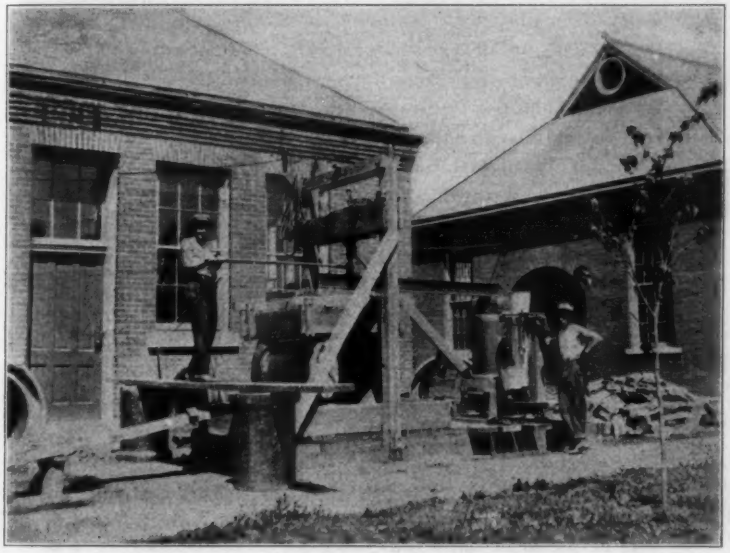
Thus it appears that a great modern Land Grant engineering school of today ought to maintain three main lines of work: Professional engineering instruction; engineering extension, including trade school courses; engineering experiment station.

The Iowa State College has formally organized at one institution all three of these great lines of engineering educational work. Professional engineering instruction was inaugurated with the opening of the College in 1869; the Engineering Experiment Station became a distinct department with specific appropriation in 1904; and the department of engineering extension was established by legislative action in 1913.

By action of the State Board of Education the heads of the engineering departments constitute the engineering experiment station council. They have active administrative control of its operation, and also initiate and outline much of the research and experimental work. All told, there are twenty-four technically trained experts giving either part or full time to the station work. Practically every interest of industrial Iowa is represented in the station staff, and its

field covers drainage, structural work, hydraulics, highway engineering, municipal engineering, agricultural engineering, electrical and mechanical engineering, geology, physics, mining, chemical engineering ceramics, and all other branches of the great profession of engineering.

Since its establishment, first importance has been attached



TESTING VITRIFIED CLAY SEWER PIPE.

to the research and investigational work, along lines of interest and value to the various industries and people of Iowa. Such investigations are directed from a practical viewpoint. They are intended mainly to solve engineering and industrial problems peculiar to Iowa, as well as to add to the common store of scientific and technical knowledge.

Thirty-seven bulletins have already been published, sev-

eral others have been written up ready for printing, and some forty special technical investigations are at present in progress in all stages of completion.

The titles of the last ten bulletins published are as follows: History of Road Legislation in Iowa; Costs of Producing Power in Iowa with Iowa Coals; The Determination of Internal Temperature Range in Concrete Arch Bridges; The Theory of Loads on Pipes in Ditches, and Tests of Cement and Clay Drain Tile and Sewer Pipe; A Topographical Survey of the Spirit and Okoboji Lakes Region; House Heating Fuel Tests; The Use of Iowa Gravel for Concrete; Report of the Investigations on Drain Tile of Committee C-6, American Society for Testing Materials; Illuminating Power of Kerosenes; Electric Central Station Operation in Iowa.

Ten samples of the investigational "projects" now under way are as follows: Load Distribution on Bridge Floors; Tests of Concrete made with Graded and Ungraded Aggregates; Drainage for Farms—study of run-off, ground water flow, effect on crops: Study of Refractory Clays in Iowa; Making and Storing of Ice on the Farm; Comparative Value of Various Kinds of Iron and Steel for Bridges and Culverts; Study of Oil Engines for use in Electric Central Stations; Service Requirements of Pavements in Iowa; Service Tests of Prepared Roofing Materials: Tests of Concrete Tile with Various Types of Reinforcing.

One of the most important branches of the station work is its good roads experimentation. A special legislative appropriation is made for this purpose, and while the work is articulated with that of the station proper, still the fund is expended strictly for good roads experimentation. Common use of men, laboratories and equipment renders more efficient and effective work than would be possible in separately equipped and wholly independent quarters. Hearty coöperation with the State Highway Commission makes possible a wise selection of problems for investigation, and has resulted

in savings of public moneys totalling many times the cost of the entire work.

Ample facilities are available for tests and analyses of practically all materials. For such work a reasonable charge is made to cover safely the expense to the station. It is in-

PRACTICAL LECTURE TO WORKMEN IN RAILROAD SHOPS, CEDAR RAPIDS, IOWA.

tended that this branch of the work shall be self-supporting and so not hamper the station in the carrying on of its research and industrial development work.

Contributory to the research, investigational and testing work is the gathering and compilation of standard and new data on construction materials; design, construction and operation of mechanical plants and devices; industrial economics; costs and characters of public improvements; and like

information of more or less general interest. Such data in the possession of experts familiar with their application become of utmost educational value to public service officials, officers of companies and organizations, and to a greater or less extent to the general public. Through a technical service bureau, maintained jointly by the engineering experiment station and the department of engineering extension and in charge of a competent industrial engineer, such data are made available for such educational purpose. Upon proper request a representative of the Bureau will visit the municipal, county, state or other public officials and render such educational service as will enable them more intelligently to perform their duties in connection with such improvements as are contemplated.

The engineering extension department is in charge of Director Kenneth G. Smith, formerly of the University of Wisconsin Extension Division, in charge of the Milwaukee District. His experience there enabled him to make a comparative analysis of the Iowa situation and adapt the work more readily to its need.

Six men give full time to the work, and an industrial engineer divides his time between station and extension work in connection with the Technical Service Bureau. Eight other instructors devote part time to the work at the college. Another eight men have been employed on part time as local instructors of evening classes in various cities of the state. Other experts are employed from time to time for institutes and short courses.

The act of the legislature provided for trade school work as well as extension. As a foundation for the trade school courses, two-year general sub-collegiate courses were organized at once. The following year specialized courses were introduced for surveyors and roadmakers; electrical workers and stationary engineers; mechanical draftsmen and artisans in mechanics; structural draftsmen and building inspectors.

A winter short course for painters and decorators was conducted during the winters of 1913–14 and 1914–15. This work constitutes a new departure in trade-school instruction. However, there is a strong demand for the extension of similar work to a number of short courses in different parts of the state, with a course at Ames at least three months long. The telephone companies and employees are demanding special trade and professional telephone engineering courses at Ames and a short course for telephone employers in every county. The carpenters and builders, the plumbers and steam fitters and the stationary and tractor engineers have already made somewhat similar demands.

During the two winters past, automobile institutes have been conducted in many cities of the state for the instruction of owners and users of cars. These institutes have met with favor, and requests for them far exceeded the facilities of the extension department.

Probably the most important part of the engineering extension work consists in the development of correspondence study, in coöperation with personal supervision from traveling instructors, and local evening and day classes under part-time resident instructors. By this means every mechanic in the state is being afforded an opportunity to secure technical educational training at home and at nominal expense, while continuing to earn his living at his trade. There is an "organizer" constantly in the field organizing the work which is arranged in coöperation with public schools, Y. M. C. A.'s, the commercial clubs, the factory owners and other employers, and the labor organizations.

The funds available annually for the engineering research and extension work are as follows:

Engineering experiment station	$15,000	
Good roads experimentation	10,000	$25,000
Engineering extension		25,000

Thus, the Iowa State College, through its engineering ex-

periment station and engineering extension department, is endeavoring:

First, to assist in the industrial development of the State of Iowa, and second, to carry usable technical education to the industrial classes, to the general public, and to public officials who are unable to come to Ames.

This work, together with the high grade professional engineering instruction at the college, should most nearly return to the people of the state, value received for the funds which they contribute for its support.

ANNOUNCEMENT

The Summer School of Management, Third Year. A summer course in Scientific Management will be held for three weeks during August, 1915, in Providence, R. I. This course is especially designed for professors of Engineering, Economics, Psychology, and Business Administration. For further particulars apply to Frank B. Gilbreth, 77 Brown Street, Providence, R. I.